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Volume XXII.—Part III. October, 1901.

JOURNAL

OF

THE SANITARY INSTITUTE.

REPORT ON THE WORK OF THE COMMITTEE APPOINTED BY THE SANITARY INSTITUTE OF GREAT BRITAIN TO PRACTICALLY TEST VENTILATING EXHAUST COWLS.

DEDICATION.

Many years ago when the subject of ventilation first began to attract a large amount of public attention, a committee was appointed by the Sanitary Institute for the purpose of testing the efficiency of the various Cowls and Terminals which were being introduced, in order to give the public some reliable means of judging of their merits.

The committee consisted of: Sir Douglas Galton, Mr. W. Eassie, and Mr. Rogers Field; Mr. J. Wallace Peggs was afterwards added.

The committee soon found that before they could arrive at any measure of the comparative value of the Cowls and Terminals tested, they must establish some standard for the instruments used for measuring the velocities of the air currents. A large part of their labour was therefore directed towards establishing a standard value for the reading of anemometers and air meters.

In the course of these experiments, and during the trials of Cowls and Terminals, so many variable conditions had to be taken into account, certain winds and states of the weather waited for, and so many experiments made, that the members of the committee, who were busily occupied in other pursuits, found that as they tried to digest the mass of records of experiments, the months were passing into years, and the years into decades, with the work still unfinished; and as one by one the members of the committee passed away, the bulk of the work by choice or by necessity fell upon Mr. Rogers Field.

Mr. Rogers Field, although a busy professional man, devoted regularly a portion of his time to the direction of the observations and experiments, and to the consideration and reduction of the records. How much this time must have amounted to in the course of the twenty-four years that the experiments had been going on, no one knows, but there is no doubt that it was a valuable item, even compared with the £2,000 which he personally contributed towards the expenses.

Shortly before Mr. Field's death, when he was in failing health, the records were taken over by the Institute. After his death no member of the committee remained, and at the request of the Council Mr. W. N. Shaw, of the Meteorological Office, undertook to bring to a close the experiments and to superintend the preparation of the report. So voluminous are the records, that although the tabulation of the results was in an advanced state, and many diagrams had already been plotted for the report, it has taken more than twelve months for the two assistants who were in charge of the work at the time of Mr. Field's death to complete the report for issue, under Mr. Shaw's superintendence.

The subject was one in which Mr. Field took an absorbing interest, especially in the latter years of his life, and the Council of the Sanitary Institute feel that it is a fitting memorial to his labours in this and other branches of sanitary engineering to dedicate this report to his memory.

PREFACE.

IN the Spring of 1900, when the death of Mr. Rogers Field, the last of the members of the Cowl Committee, had brought the prolonged labours of the Committee to a close, the Council of the Sanitary Institute did me the honour of inviting me to undertake the duty of preparing a report on the results of the experiments.

With but little time at my disposal, it was not in my power to comply with the request. There were, however, still employed in working out results on the lines laid down by the Committee two of Mr. Field's assistants, Mr. W. D. Matthews and Mr. H. Farmer, who had been engaged upon the work for many years, and who were well acquainted with the enormous mass of documents that had been accumulated by the Committee during the 23 years of its activity; I had for some time past taken a practical interest in the investigation of the laws of flow of air through tubes, and I was desirous of making what acknowledgement was in my power of the skill and energy, as well as self-sacrifice, so conspicuously exhibited by Mr. Rogers Field, and his colleagues on the committee, in a matter that is undoubtedly of great industrial and scientific importance, and accordingly I undertook to supervise the preparation of the report.

The work was left by the Committee in a somewhat peculiar position. After many years of almost fruitless labour bestowed upon testing instruments to be used in the inquiry, and obtaining even with the elaborately-tested instruments results that were hardly capable of generalisation, the idea was suggested of making experiments on a series of "terminals" differing from each other in the dimensions of some one element of their construction and determining how this development affected the flow of air along the pipe which it surmounted. The idea seems to have originated with Mr. Farmer's observations of the behaviour of smoke issuing from the terminals which are reproduced in this report, pp. 388 to 393, and to have led to a very instructive and interesting series of results which were approaching completion at the time of Mr. Field's death.

At the same time no narrative of the proceedings of the Committee existed. The papers include innumerable commencements of the preparation of a report, an elaborate synopsis of the items to be dealt with, materials more or less complete for an introduction dealing with the history of cowls from the earliest times, materials for illustrating the introduction, and endless summaries, tables and diagrams of experiments and results. Most of these are in want of finishing touches, which only those who originally designed them could give effectively. In what follows a selection of some of the fragmentary attempts at drafting portions of the report and materials collected for that purpose is given as an introduction, and appears as Part I. The tissue connecting the sheets of tabulations and diagrams embodied in Parts II. to V. had to be woven from the first with such assistance as the "synopsis" and fragmentary marginal notes and comments could give.

The curves for interpreting the readings of the air-meters had been completed and were in actual use, and the laborious steps by which they were arrived at could be followed; the tests of the anemometers waited only Mr. Field's decision as to the correction for "mitwind" in the calculation of the readings of the "1-inch cups." It would appear that the want of agreement of the readings of the different instruments caused some hesitation about accepting a final value. All the evidence seems to have been set out, but the verdict was not given, and I have had to take up the difficult task of a jury and pronounce "Yes" or "No" upon the questions which were to be answered for the Committee upon the facts they had collected.

The comparisons of the readings of open pipes mounted side by side were expressed in a number of elaborate diagrams, which were apparently prepared for publication and are accordingly reproduced. But the number of different coloured inks used in their preparation would seem to indicate a mode of reproduction which it would be difficult to carry out, and it is to be feared that in this, as in many other particulars, those who wish to realize the full extent of the Committee's careful work must consult the original diagrams, which are in the possession of the Sanitary Institute.

The work upon the comparison of the different terminals and cowls will, I hope, be sufficiently represented by the tables and diagrams which Mr. Matthews and Mr. Farmer have prepared, and which I believe will be found to be the most interesting portion of the report. The Committee's legacy in this department consists of 200 sheets of "Complete Tabulation" of the experiments, besides the original notebooks and innumerable abstracts. I have endeavoured to secure a sufficient indication

of what can be found in the original documents, without attempting to reproduce them in their completeness.

I feel bound to refer to two points of criticism upon the work. One concerns the use of the word "efficiency" for a terminal or cowl as expressing the result of the experiments. The word is only appropriately employed for a numerical constant or factor, which is characteristic of the terminal or cowl, and of that alone. In an introductory note to Part V. of the report I have given my reasons for thinking that the ratios obtained by the Cowl Committee depend upon the other part of the experimental arrangement, and not upon the terminal portion only, and that in consequence the word is not strictly applicable (see pp. 341 to 346). But I ought to say that this does not invalidate the effectiveness of the results and diagrams which compare together terminals differing in one dimension only, all other portions of the apparatus remaining the same.

The other point concerns the plan of dealing with the apparatus for testing by the method of averages of a large number of experiments. Suppose, for example, that 100 experiments testing the effect of wind direction, upon the computation of a result upon which a subsequent measurement is to be based, give results varying among themselves between 90 per cent. and 110 per cent. with a mean of 100 per cent. It is hardly a sound inference to say that in using the computation for testing a terminal the proper number to take for the computation in that particular case is 100 per cent. All that can really be said is that the computation from a single experiment may be 10 per cent. in excess or defect of the mean, and that a single measurement must be understood to have that uncertainty attaching to it. There is some ground for saying that if the measurement of the terminal were repeated 100 times, the mean value should be taken in preference to any other. This, however, leads to the consideration of "probable error" and other questions which the Committee did not deal with, and I have endeavoured to represent the results as they were left by the Committee. I have not attempted any discussion of them; I shall have succeeded in the task I undertook if those who are so far interested in the matter as to wish to push inquiries into the generalisations that can be obtained from the results are able to find the materials they require, either in what is now published or in the original documents to which this publication may be regarded as a guide.

Any one who does so pursue any point that suggests itself cannot fail to be convinced of the desire of the Committee to place at the disposal of the Institute full and complete knowledge on all the points arising in the

course of the inquiry, and their determination that the enter
not fail for any want of energy, care, or skill on their part.

It is a matter of profound regret that the results were not
the Institute by those who alone could do it most effectivel
sacrificed so much in the endeavour to place the testing of
a sound scientific basis.

W. N. S

June 17th, 1901.

An epitome of the Contents of the Report and Lists and Diagrams is given at p. 447.

PART I.—INTRODUCTION.

A SELECTION OF NOTES, CORRESPONDENCE, AND MEMORANDA FROM THE DOCUMENTS PRESERVED BY THE COMMITTEE.

I.—*Notes on previous Experiments on the action of Wind on Open Pipes and Cowls. Drawn up by Mr. J. W. Peggs* (*27th August*, 1887).

Experiments on the effect of wind passing across the mouths of tubes indicated by the flow or pressure of liquids. ("*Mechanics Magazine,*" *1825.*)

A saucer was filled with water into which was put a glass funnel, the smaller orifice being above the water about 8-in., then the wind passed over the top from a kitchen bellows. The result was that the water ascended in the funnel, filled it, and was blown over as long as the operation of blowing was continued.

The next trial was with a 30-in. barometer tube, open at both ends, and the result was as before, only the water started up with much greater rapidity than with the funnel.

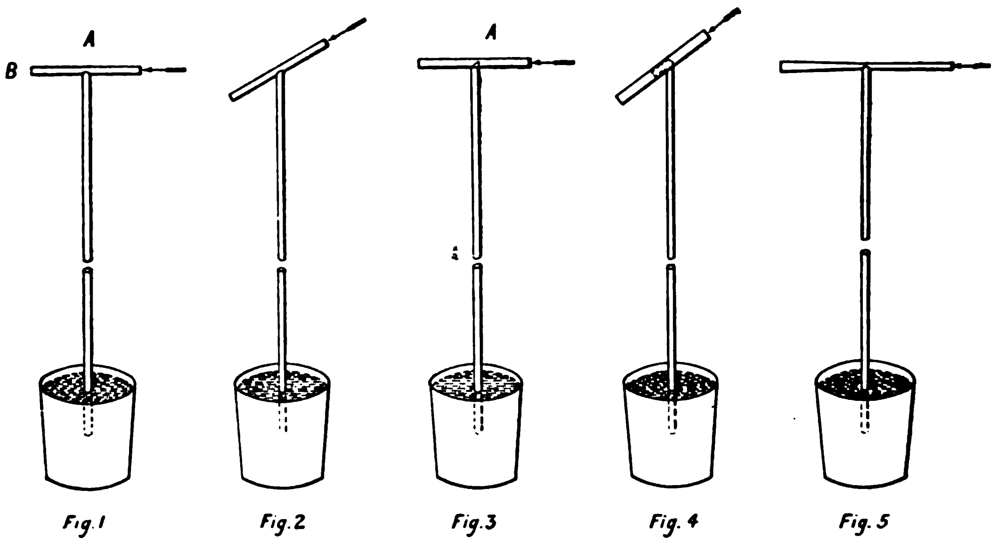
THOMAS EWBANK.—*Experiments on the effect of wind passing across the mouths of tubes at various angles, as indicated by the flow or pressure of liquids.* (*1834–35.*)

These experiments were made with small leaden, block tin, and glass tubes, $\frac{3}{8}$-in. and $\frac{1}{2}$-in. bore. The tubes $\frac{3}{8}$-in. bore were of different lengths, (12-in. to 36-in.), and placed in an upright position, the lower end being dipped into a tumbler containing a little water.

Across the top of the upright tubes shorter tubes were placed, generally $\frac{1}{2}$ in. bore, and inclined at different angles to the vertical tube, as shown in the sketches, Diagram 1, p. 208. Conical cross tubes were also employed.

The blast was effected simply by applying the mouth to one end of the cross tube and blowing through it. The effect of the blowing on the water in the vertical tube was then noted.

The most important results may be briefly summarised as follows :—



The vertical tubes are continuous, the gaps shown indicate that the whole length of the tube is not given.

Diagram 1.

In fig. 1, instead of the liquid rising in the vertical tube, air was forced out through the water in the tumbler. Various portions of the end *b* were then cut off without changing the result until *a b* was only ½-in. long, when the air no longer descended, but no rarefaction took place in the vertical tube.

In fig. 2 the same result was obtained as in fig. 1. In fig. 3 the vertical tube was made to project into the cross tube, and was cut obliquely as shown in the sketch at *a*. On blowing through the cross tube, in the direction of the arrow, rarefaction took place in the vertical tube, and the water rose in different trials from 20 to 30 inches.

In fig. 4 the vertical tube was carried into the cross tube and curved as shown in the sketch, thus leaving an annular space ⅛-in. wide. On blowing through the cross tube in the direction of the arrow, the water rose in the vertical tube from 20 to 30-ins. This result was improved by enlarging the annular space.

In fig. 5 the cross tube was coned as shown in the sketch, and different sized cones were tried. The best result was obtained with a cone 9-in. long, ¼-in. diameter at the smaller end, and ⅜-in. diameter at the larger end, and in this case the water rose 31 in. in the vertical tube.

THOMAS EWBANK.—*Experiments on the comparative value of various forms of chimney caps and ventilators carried out by Thomas Ewbank and Jordan L. Mott at New York, and communicated to the Franklin Institute, Philadelphia, 1st July, 1842.*

The blast was produced by three cylindrical bellows worked by a steam engine, and was conveyed through a 5-in. pipe terminating in an orifice 3-in. diameter through which the air issued in a horizontal direction. Eight inches in front of the orifice a vertical glass tube 28-in. long, 1¼-in. bore, was placed, its lower end descending into a vessel of water, as shown on Diagram 2, fig. 1. The upper end of this vertical tube had a ferrule to which the caps experimented on were fixed.

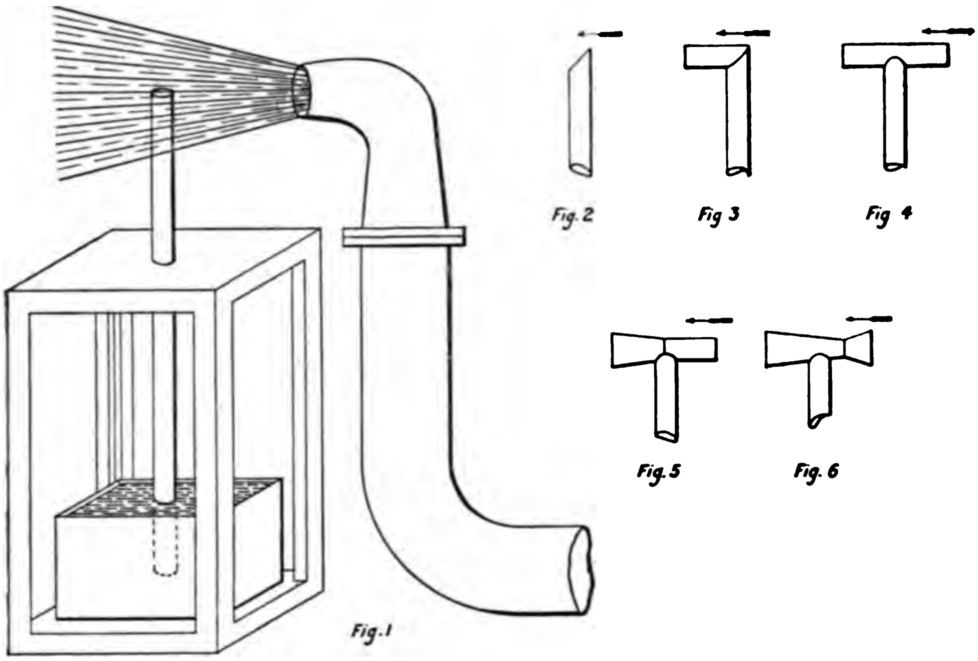


Diagram 2.

The result of these experiments may be briefly summarised as follows: When the ferrule at the upper end of the glass tube was placed in the centre of the blast no rarefaction was produced, and the water was neither elevated nor depressed within the tube.

Cap fig. 2, consisting merely of a plain tube cut off at an angle, and fig. 3, consisting of a right-angled bend, when placed in the centre of the

blast blowing in the direction of the arrows, gave nearly similar results, and raised the water in the vertical tube from 1½ to 2½-in.

Cap fig. 4, consisting of a cross-piece on the vertical tube as per sketch, gave, when the blast was in the direction of the arrow, no rise of water in the vertical tube. When the blast was at right-angles to the cross-piece the water rose two inches, and when it was at 45 degrees to the cross-piece the water rose 4 inches.

Cap fig. 5, consisting of a conical cross-piece, caused the water to rise from 16 to 18 inches.

Cap fig. 6, similar to the last, but with a conical piece at the blast end, caused the water to rise from 22 to 24 inches.

BOSTON EXPERIMENTS.—*Experiments on ventilation carried out by a Committee of the American Academy of Arts and Sciences, Boston, and reported by Dr. Wyman at the meeting in March, 1848.*

In these experiments the blast of air was produced by means of a revolving fan and was conducted into a straight square trunk 10 inches by 10 inches. In the mouth of this trunk was a tube of tinned iron 1¼-in. diameter and bent at a right angle to carry the caps, the upright branch of this tube, about 6 inches long, reaching to the inside of the mouth, while the horizontal portion, about 5 inches in length, reached within about 2½ inches of a coil of lead pipe 53 feet long. The connection between the pipe carrying the caps and the lead pipe was made by a short glass tube, for the purpose to be explained further on.

The fan was worked by hand, the blades being made to revolve at 300 revolutions per minute by means of multiplying gear. The velocity of the blast as it issued from the trunk was measured by observing the deflection of a toy marble suspended by a silken thread in the centre of the mouth of the trunk. In order to ascertain the velocity which the observed deflection indicated the same marble was suspended at the mouth of a tube 1-in. diameter, through which air was forced at a known velocity from a model gas holder. The velocity thus ascertained was 10·36 feet per second, or 7·06 miles per hour, and this velocity was maintained throughout these experiments as the fan was always revolved at the same rate.

The velocity of the induced current in the coil of pipe was measured by taking advantage of the well-known action of chlorine upon iodide of potassium dissolved in starch. A piece of paper wetted with the prepared starch was suspended within the glass tube and chlorine gas was allowed

to enter the end of the coil of pipe. The chlorine was carried along with the current until it reached the starched paper which it instantly dyed a deep blue. The interval between the chlorine being admitted into the pipe and the blue color appearing on the starched paper was observed and this indicated the time the induced current took to travel 53 ft. from which the velocity was calculated.

In the first place a perpendicular fixed tube 1¼-in. in diameter with a horizontal top was tried.

Then a similar tube cut off obliquely at an angle of 45° with the opening turned away from the blast, then a number of elbows, plates and cowls.

The induced current caused by the blast on the ventilator is measured by the velocity through the 1¼-in. pipe.

In the perpendicular fixed tube the velocity is 0·728 ft. per second, and in the other arrangements ventilators varied from 0·609 to 2·21 ft. per second.

If we take the upcast in the open pipe as the datum as in the Kew experiments, then Dr. Wyman's experiments shew that the efficiency is generally much greater than that of an open pipe, being from twice to three times greater, excepting in the case where the reading is 0·609 ft.

Experiments on the Efficiency of Open Pipes and Wolpert's Cowls, by Dr. Adolf Wolpert, carried out in 1877. Second Edition of "Ventilation und Heitzung," p. 387.

The blast was produced by a centrifugal fan making 1,500 revolutions per minute. The blast came vertically upwards through a tube 10 centimetres in diameter, and 54 centimetres above the ground.

The velocity of the blast was measured by one of Wolpert's statical anemometers, and also by a water manometer. The cowls and open tubes to be experimented on were placed horizontally over the blast, and at distances varying from $\frac{1}{10}$ meter to 1 meter above the blast tube. No air was allowed to pass through the cowls or open tubes, but the exhausting power was measured by a water manometer in connection with exhaust tube, and the velocity was calculated from the manometer. The velocity of the blast varied from 31 meters per second (69·44 miles per hour) to 8 meters per second (17·92 miles per hour). Experiments were made with plain open tubes of various diameters, viz., 20, 40, 60, 92 millimeters, and also with Wolpert's Cowls new and old pattern.

The conclusions he arrived at are as follows :—

That a plain vertical open tube is a very good exhaust apparatus when the wind is horizontal or only slightly inclined. That the frequently occurring down-draughts, and the admission of rain, necessitate the construction of other apparatus, even if these, under many circumstances, give a smaller efficiency than open pipes.

According to Wolpert's experiments the exhausting power, with a horizontal wind, is as follows :—

For an open pipe the exhausting power is two-thirds of the velocity of the wind passing across it.

For Wolpert's new cowl the exhausting power is one-half of the velocity of the wind passing across it.

For Wolpert's old cowl the exhausting power is one-third of the velocity of the wind passing across it.

Experiments with blasts at different angles show that neither of Wolpert's cowls were subject to down draught.

Experiments on Ventilation or Cowl Testing, but not at Kew, by S. Stevens Hellyer. "Plumber and Sanitary Houses," Fourth Edition, p. 433. Experiments carried out in 1880.

The experiments were carried out on two 4-in. lead pipes. The pipes were fixed upon a wall outside Mr. Hellyer's factory and were 33-ft. long. There were several bends in the course of the pipes, but care was taken to have the bends similar in both pipes. The pipes were continued 6 or 7 feet above the parapet of the wall, and were placed 4 feet apart at their upper ends.

Two different methods of testing were adopted:

In the first method, the pipes were connected by a V bend at their lower end, and a fan meter made by Negretti & Zambra was fixed in one of the limbs of the V-shaped pipe where it could be seen through a glass front.

The trials were made upon what Mr. Hellyer calls the "Pull Devil pull Beggar" principle. In the first place a cowl was fixed upon one of the pipes and the other left open. At the end of an hour a reading of the fan meter was taken, and if this showed that the cowl had drawn air through the open pipe, it was assumed that the cowl was better than the open pipe and *vice versâ.*

In the next place a cowl was fixed on each pipe and observations taken in the same way to determine which cowl was best.

It will be noticed that by this method the fan meter was read backwards as well as forwards.

In the next method the two pipes were taken independently without the V-shaped pipe, and two fan meters, one being fixed at the foot of each pipe. A cowl was placed on each pipe and tests were made at intervals of 10 minutes, 1 hour, and 2 hours. Readings of the fan meters were taken at the end of the interval, and then the cowls were changed over so that each cowl was on a different pipe.

The experiments show that a few of the cowls gave worse results than an open pipe, but most of them gave better results, the gain being from 3 to 18 per cent.

Mr. Hellyer's own conclusion about the cowls is: "Taking all the tests, the palm of victory must be given to Mr. Buchan, and the results given in the various tables warrant the author in placing his own about second on the list."

ADDENDUM.

Additional materials for completing the introduction thus commenced by Mr. Peggs are contained in two books of newspaper cuttings, entitled "Principal Experiments on Ventilation by Cowls and Other Automatic Means," and "History of Ventilation by Cowls, &c.," extracted from the *Plumber and Decorator*, January, 1885 to August, 1889.

In 1898-1900 a complete synopsis of the work carried out by the Committee was prepared with a view to the preparation of the Report to be presented to the Institute; but no draft of a Report was prepared beyond some rough notes by Mr. Field and Mr. Peggs indicating the general lines proposed to be followed.

II.—*Chronological Table of Work done.*

(Drawn up probably in October, 1896, and extended to the time of publication, 1901.)

1876–7.	Experiments* by Mr. Field and Mr. Peggs, 1876–7.
1877.	Exhibition of The Sanitary Institute at Leamington in 1877.

* Between December, 1876, and July, 1877, a number of experiments were made by Mr. Peggs and Mr. Field in a garden at Stoke Newington. So far as can be ascertained the experiments consisted in comparing the flow of air through a cowl, read by means of an air meter attached presumably to a pipe, which was surmounted by the cowl under observation, with the simultaneous readings of an anemometer. Various cowls

1878.	Sub-committee (*) appointed to test Cowls exhibited.
1878.	Experiments (†) at Verification House, Kew Observatory, 1877–8.
1878.	Mr. Peggs' paper at Paris (†).
1878.	Report of sub-committee in 1878 (*).
	Criticisms (‡) as to coning and as to variation of upcast in different pipes.
	Further experiments to elucidate this.
1879–80.	Experiments on 3-in. Air Meters with experimental gas holder at Sugg's, 1879–80. (Report, p. 238.)
1880.	Experiments on 6-in. Air Meters with experimental gas holder at King's Cross, 1880. (Report, p. 251.)
1881–2.	Experiments on 3-in. Air Meters at Sugg's, 1881–2, with experimental gas holder. Such great discrepancies in the results that it seemed unsafe to use them. (Report, p. 243.)
1884.	In 1884 a special gas holder was fitted up at Mr. Field's offices at Cannon Row and very accurate experiments tried, which cleared up the whole matter and showed that the discrepancies were due to air currents, and to different temperatures of water. (Report, pp. 244.)
	[1884, August. Mr. R. O. Rymer Jones commenced experiments at the Hut in the Old Deer Park under the direction of the Committee.]
	Tested 6-in. Air Meters for low velocities.
1887.	And tried 3-in. and 6-in. at Old Deer Park. (Report, p. 265.)
1884–92.	Experiments at Old Deer Park, 1884–92. Mr. Rymer Jones made roughly 2,000 experiments.
1893–7.	Subsequent experiments, say 4,000.
1893.	Mr. A. W. Ackermann and Mr. W. D. Matthews engaged; books checked and reductions made.

were tried in this way, as well as an Open Pipe. The results appear on thirty-four foolscap sheets, but no final reduction of the numbers has been completed, so that the effective comparison of the cowls is not available. In view of the more elaborate arrangements subsequently adopted, it seems now unnecessary to do more than mention the existence of these readings.

(*) Names of Committee:—Captain (afterwards Sir) Douglas Galton, C.B., F.R.S., who died 10th March, 1899; Mr. Rogers Field, B.A., M.Inst.C.E., who died 28th March, 1900; and Mr. William Eassie; after Mr. Eassie's death in August, 1888, Mr. J. Wallace Peggs, Assoc.M.Inst.C.E., became a member of the Committee, but died on 24th Feb., 1899.

(†) See "Sanitary Record," September 13th, 1878.

(‡) These criticisms are preserved in book of cuttings among the papers collected by the Committee and now preserved at The Sanitary Institute.

1894. Open pipes reduced and wind compasses prepared. (Report, p. 302.)

1894. Investigation of abnormal experiments showed that a number of experiments required to be rejected as unreliable; certain rules were drawn up (such as line of pipes, outside pipes differing 10 per cent.) so that the rejections might be made on a uniform system, and each individual experiment was examined by Mr. Field. A large number were rejected. (Report, pp. 299 and 346.)

1894. When this was done and complete tabulations made it was found that other experiments were wanted, and supplementary experiments were commenced in 1894.

Special instructions were given only to try under favourable conditions, and stop if experiments were abnormal.

These supplementary experiments showed that a number of points required working out.

1895. March. Mr. H. Farmer engaged in place of Mr. Rymer Jones.

Curves prepared for:—

1895. Plain Diverging Tubes.

1895. Different-sized Caps over pipes, etc.

1895. Different heights as Hill Curve* on same day. (Report, p. 405.)

It was found these must be tried on the same day with a favourable wind, leading to great delay.

Sliding caps were tried to save time, with set screws, but subsequently it was found that these affected the results and had to be repeated.

1895–6. These led to a great expenditure of time and further results and discoveries, and eventually 3,200 additional experiments have been tried, making 5,200 altogether, and as valuable discoveries have been made quite recently some more experiments will be wanted.

1896. Experiments with twirlers (Upcast and Down-draught). (Report, p. 382).

1896. Experiments with sugar loaf and sugar loaf Hill Curves.* (Report, pp. 363 and 411.)

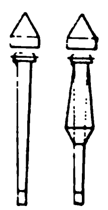
(*) Hill curves are understood to mean curves representing the results of a series of experiments generally completed on one day, to ascertain the effect of difference of position of a rain-gauge cap, or sugar-loaf terminal, over pipe or diverging tube, or any other one variable. Such curves are represented in the Report (Diagrams AE to AP, p. 405, BD, p. 414, and BU, p. 420.)

1897.	Louvres and feathers found to be advantageous in certain cases. (Report, pp. 226—228.)
1898–1900.	Downdraught experiments with board at various distances behind centre of Cowl or Terminal, p. 437; experiments with Injectors (Report, p. 434); upcast experiments with jointed pipes, twirling tops, and improved single louvres with feathers; also over 1,000 experiments on various terminals with sloping roof, p. 334.
1900–1901.	Adding to complete tabulation and preparing rough draft for completing and publishing report.

III.—*History of the Development of Tests on Louvre Terminals.**

12th November, 1897.

1897.	
3rd July 5th July	Comparison of Sugar Loaf and Louvre.
10th August	Comparison of louvred diverging tube and same encased in cylinder. See also 21st Oct., 1897.
16th August 16th Sept.	Comparison of uncut and cut cylindrical Louvre.
16th Sept. 21st Sept.	Comparison of Louvre fitted with four feathers and ditto with four $\frac{3}{16}$″ dia. brass wire stays.
17th Sept.	Lobster with feathers.
4th Oct. 5th Oct. 22nd Oct.	Comparison of 4, 7, and 9 feathers without cap. do. do. do. with cap.
11th Oct.	Comparison of 7 and 9 feathers with and without cap.
20th Oct.	Comparison of 7, 9, and 11 feathers with cap.
21st Oct	Comparison of two forms shown in sketch.
21st Oct. 23rd Oct. 2nd Nov.	To find best length of feathers below Louvre.
3rd Nov. 4th Nov.	To find best length of feathers inside Louvre.
3rd Nov.	Comparison of 4 and 9 feathers with small top Louvre. Result, efficiency same. See smoke tests on 4th Nov.
10th Nov.	To find best diameter for top of Louvre with 9 feathers.
Nov., 1897, and Feb., 1898.	Smoke Tests.



* See Table XXVII., p. 349, and Diagrams 57—82, p. 397.

IV.—*Hill Curves.*

7½-IN. CAP OVER 3-IN. PIPE.

The first attempt was made on the 23rd August, 1895. On this occasion "Flush" seems to have come out too low, viz.: Ratio ·84, inserted ½ in. being ·86, and ½ in. above being 1·04.

On account of the great difference between Flush and ½ in. above, another attempt was made on the 4th October, 1895, with the ¼ in. above included. This second attempt was frustrated by heavy rains, thus preventing completion of curve.

A third attempt was made on the 25th October, 1895, and was fairly successful. The Robinson Cups were out of order on this date.

See Diagrams 65—71, p. 405, Diagram 74, p. 414, and Diagram 80, p. 420.

V.—*Causes of Delay.*

Waiting for a suitable wind. A very good wind is wanted for these curves, as something like twenty-five experiments have to be made, and all of these have to be done in the same wind.

Wind velocity dropping, causing rejection of experiment.

Wind direction changing to "line of pipes," causing rejection of experiment.

Outside pipes differing by 10% or more.

Rain; meters have to be taken out.

Gusty winds.

Ratios differing by 5% or more.

Sliding Caps.—A great number of experiments were made with Sliding Cap with zinc studs, which were found not to be reliable.

King's Cross note-books checked and experiments averaged.

History of the consecutive readings of King's Cross Meters (671, 673, 674) had to be made.

Standard 3-in. and 6-in. Curves re-plotted.

Open-pipe sheets re-worked from revised curve.

Kew note-books (forty in number) checked.

Wrong position of meters noted, in some cases caused the following alterations: (1) Complete Tabulation; (2) Wind abstract; (3) Wind compass; (4) Ratio compass.

Abstract of day's work (history), prepared for doubtful days.

Examination of each individual experiment by Mr. Field for doubtful experiments which, or some of which, ought to be rejected.

VI.—*Correspondence.*

122, Sinclair Road, Kensington, W.
October 16*th*, 1895.

Rogers Field, Esq.

Dear Sir,

I happened to look in at the National Gallery to-day, and was struck by the numerous chimney caps (Fig. 1) in the pictures of Venice. It might interest you to look in there some day: if so, note the following pictures:—

Fig. 1.

No. 163, by Canale, 20 examples; see example in right hand corner.

No. 127, by Canale, 17 example: note example in left hand corner.

No. 1059, 5 examples.

No. 938, by Canale, 39 examples, and 4 with ornamental terminals (see Fig. 2).

Fig. 2.

No. 1058, by Canale, 39 examples.

No. 937, 6 examples, and one example shows signs of having been doctored (see Fig. 3).

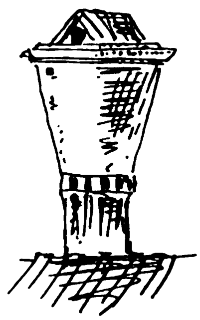


Fig. 3.

No. 210, by Guardi, shows 18 examples.

No. 812, by Giovanni Bellini—lived between 1428 and 1516—shows 2 or 3 (faint) examples: see left hand corner, house tops (see Fig. 4).

Fig. 4.

British School:—

No. 407, by Stanfield, 3 examples.

No. 370, by W. M. Turner.

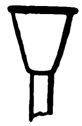
Yours faithfully,
A. W. Ackermann.

Naples,
Dec. 18th, 1895.

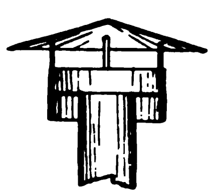
R. Field, Esq., Westminster.

Dear Sir,

A few weeks ago I did not think I should have the pleasure of seeing

those interesting Venetian chimneys we have previously discussed. I now send you a few copies (Diagrams 3 and 4, pp. 220–221) from my note book that may be of interest to you in connection with the very valuable set of experiments you are conducting. The  -shaped Venetians are not so much in fashion as in Canaletti's (artist) time, but many still remain and seem peculiar to Venice, for I have not noticed them elsewhere. They are built up of very thin bricks or stones specially shaped, and inside have a second chimney loosely covered with tiles. I was fortunate enough to see one under repair from the Tower of St. Mark's. Occasionally they are grouped in threes and fours, and run at times very large, as much as four or five feet across the top. All have vent holes near the smaller diameter. No. 15 is interesting, as so near Mr. Peggs' favourite pattern, and looks well.

No. 18 from Rome is very quaint, and also looks very well.



No. 14 is in terra cotta, modern, and much used in Milan. No. 12 is of sheet iron, and seems the favourite pattern here in Naples—as many as two dozen being on some roofs, mostly flat here; and as they do not seem to have been doctored, are apparently successful. I think their section must be of the form here shown, but cannot get near enough to get dimensions.

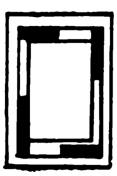
No. 1, from Milan, has a cowled top of plate, the rest in brick and plaster, which seems the favourite material.

Yours faithfully,

A. W. ACKERMANN.

Notes re Chimney in Italy, by A. W. A., Dec., 1895 (see diagrams 3 and 4, pp. 220–221):—

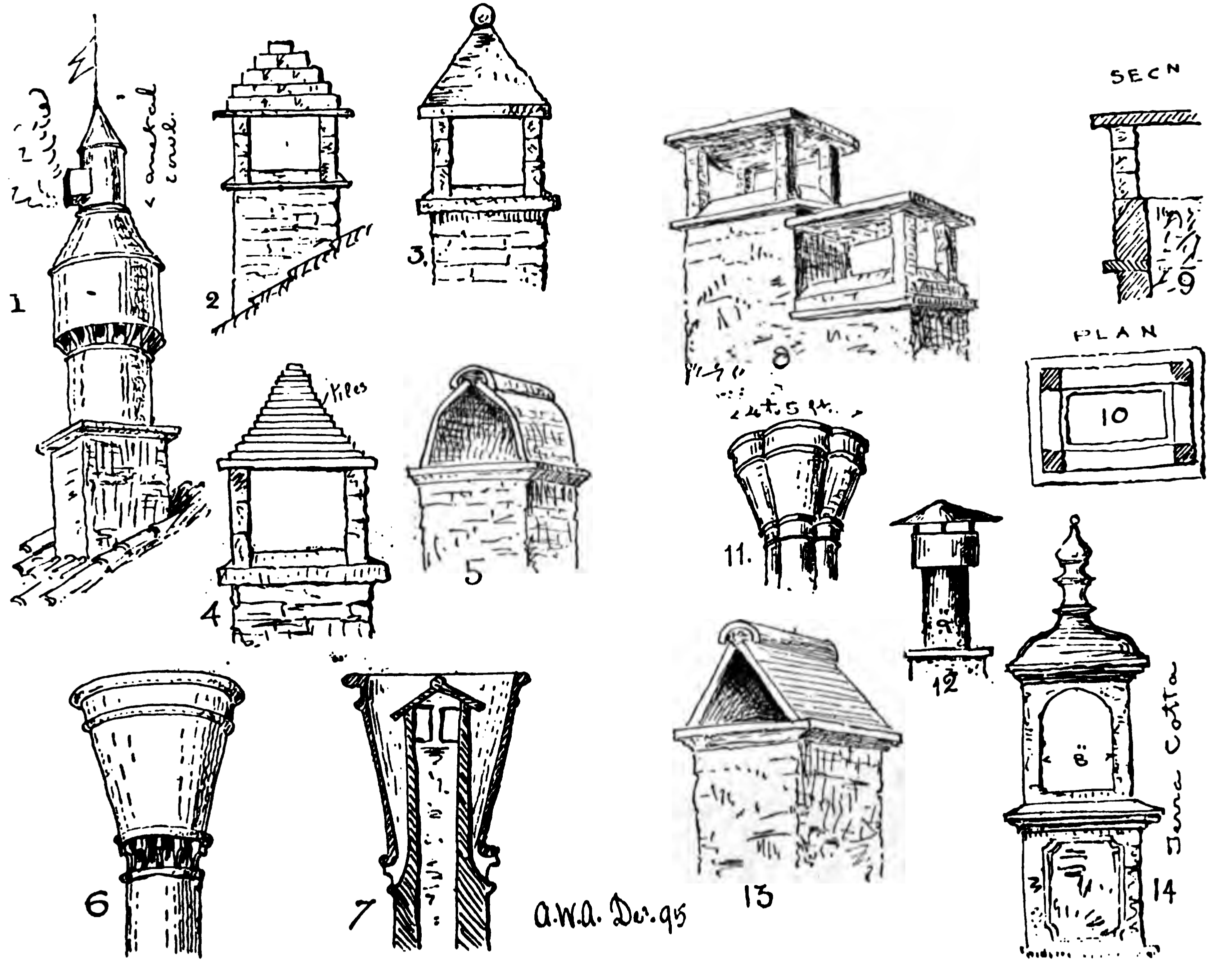
Nos. 1, 8, 9, 10, 13, and 14. Milan.
Nos. 2, 3, 4. Farmhouse between Milan and Venice.
Nos. 5, 13. Florence.
Nos. 6, 7, 11, 15, 16, 17, 19, 20, 21. Venice.
No. 18. Rome.



The commoner forms, as 2, 3, 4, 8, 17, appear to aim at as little obstruction as possible by corner columns, and in some cases the cap is supported with thin tiles, placed as here shown on plan.

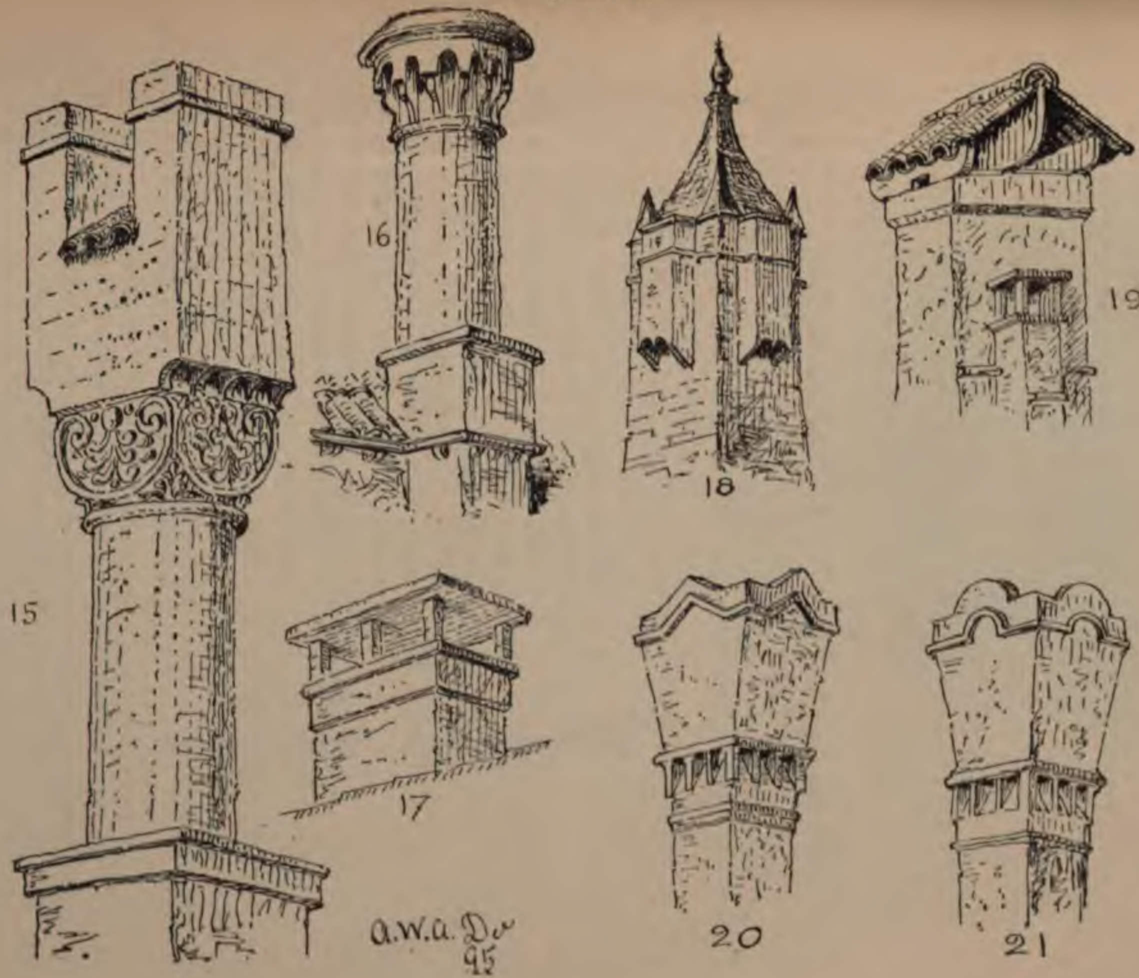
A. W. A.

Diagram 3.



1
2
3
4
5
6
7
8
9
10
11.
12
13
14
SECN
PLAN
tiles
Terra Cotta
A.W.A. Dec.95

Diagram 4.



11, Rue Boissy d'Anglas, Paris,

April 10th, 1879.

Dear Sir,

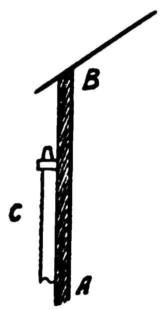
I called immediately on M. Faré (156, Rue de Rivoli). He says he cannot give his report except upon an order of the Agricultural Bureau. I am going to inquire for you and will report soon.

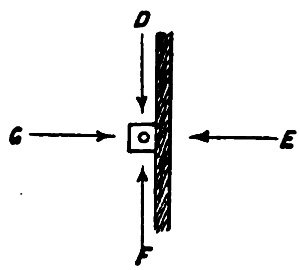
As to the experiments on cowls, permit me to give my opinion to yourself and friends.

Page 146 of my book (Traité de chauffage) you might read:

"Bien des personnes s'imaginent que l'hélice fixée à l'intérieur d'un tuyau active la sortie de la fumée: *c'est une erreur.*"

You see I did not wait your experiments to have a right opinion on the subject. See figures 87, 90, 94 to 96, 97, 98, 101, 103, 118, 125, 129, 130, 131, 164 to 182 of my book: you will find endless forms of cowls (or M. Eassie's, pages 172 to 175). More than 2,000 Patents have been taken on the subject, all copied from old things. The theory is this: 1st, Suppose a wall AB higher than the pipe C *and no wind*. The ascending power of the smoke or vitiated air will be exactly in proportion of the difference of density of the gases of the column C and the external air. 2nd, Should the wind blow from D or E or F the ascension of the smoke will be natural; but should the wind come from G its strength may be superior or equal to the difference of density I just spoke of, and will cause the effects we all know. Hence all those inventions to put a "paravent" or screen on the G side, or to force the wind to drag away the smoke as we do here with the revolving "gueules-veloup."



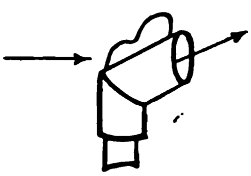


One of the most simple of the inventions is no doubt the Chinese cap, used thousands of years ago, together with proper and sufficient air ducts to supply air to fireplaces, a thing which is just as badly understood in England as elsewhere; a thing which has been done here by Gauger in 1713 (see "La Mécanique du Feu"), and reinvented or recommenced by Captain Belarius in 1832 (Mémorial de l'Officier du Génie), and twenty years afterwards by Captain Douglas Galton in his famous

ventilating fireplace, so much spoken of in all the scientific papers of the last twenty years.

Now to the cowls. Never forget the rule I laid down (last line, page 268 of my book*): 3 things are indispensable to provide ventilation—an entrance or air duct; an *exit* for vitiated air; and, last, a force. The cowls you experiment with are nothing else but "paravents"; some of them may act well, like plain open pipes, in case of strong wind, but are actually worthless, and I say more, prejudicial, in case of calm weather, *when you mostly want ventilation.*

One of the best modes of ensuring cheap ventilation (that is to say, to find the third term of the problem) and one to be used in barracks, hospitals, kitchens, etc., is to put the vitiated air of the various rooms (when possible) in contact with the smoke pipe of the kitchen, said pipe of conductible material and inserted in a main exit pipe of masonry: when you cannot resort to it, have gas or some other agent, but do not depend upon natural forces like the wind, which act like wind-mills and give you water when you do not want it.



Very truly yours,

CHS. JOLY.

I send you a few copies of my last brochure to give to your friends of the Sanitary Institute, and particularly to Captain Douglas Galton.

When you can inform me of what you are doing on your side I shall feel obliged. I subscribe to the Journal of the Society of Arts for that.

5, CANNON ROW, LONDON, S.W.,
May 12th, 1879.

M. JOLY.

DEAR SIR,

I ought to have written you before to thank you for your letters and for the trouble you have kindly taken in endeavouring to obtain M. Faré's Report for me.

I wrote to M. Tisserand, Directeur d'Agriculture, as you suggested, a letter, a copy of which I enclose, but I have not received any reply.

I have given copies of your note, "Sur la ventilation des Salons," to Capt. Douglas Galton and Mr. Eassie, and forward you per book post a copy of the

* Traité Pratique du chauffage, de la ventilation, et de la distribution des eaux. Paris: J. Baudry. 1873.

Sanitary Record of last week, in which Mr. Eassie notices your paper. I will give the remainder of the copies to other gentlemen interested in the subject when I have an opportunity.

I have referred to the various passages in your "Traité de Chauffage" (which I am sorry to say I have not yet had time to study as carefully as I should desire), but I do not see that they deal with the precise point which we are going to investigate in our cowl experiments. There can be no doubt that in a number of cases the up-current in tubes is created by difference of density of the gases as you state, but there are also many cases in which the up-current is created simply by the *passage of wind across the exposed upper end of the tube.* This we proved in our previous experiments at Kew, where we got a very strong up-draught varying with the velocity of the wind when the temperature inside and outside the building was precisely the same. It is this "induced current" due to the action of the wind, which we are going to investigate.

We intend to measure the velocity of the wind, also the corresponding velocity of the up-current, and ascertain if we can what relation the one bears to the other. This, as far as I know, has never yet been done.

We are at present engaged in testing our air meters and anemometers, so as to obtain a reliable standard on which to work. The result of these experiments as far as they go, shows that these instruments as ordinarily used, are not to be much relied upon, and if we do nothing more than obtain correct data with reference to them, I think we shall be doing good service to the science of ventilation.

What kind of air meters do you generally use for testing currents in ventilating flues?

Yours very truly,

ROGERS FIELD.

11, RUE BOISSY D'ANGLAS, PARIS,
May 14th, 1879.

DEAR SIR,

I received your letter 12th inst, also the paper; many thanks for it.

1°. M. Faré's Report.—I do not know of any other means now but to write the same (M. Tissérand's letter), and direct it,

M. le Directeur général
de l'Administration des Forêts,
au Louvre,
à Paris.

Perhaps he will answer.

2°. Anemomètres.—Here they measure the velocity of the current together with the diameter of the anemometer and calculate accordingly. But I doubt if the result is scientifically exact.

Some of the best anemometers here are made by M. E. Hardy, 6, Avenue de Lamothe, Piquet. You might write him and ask description and price of his instruments, stating for what object.

I think the object you have in view has never been tested scientifically, and you will do much good by throwing light on the questions. Your papers, like *Builder*, are full of false notions and inventions on the subject.

With much respect,

CHS. JOLY.

VII.—*Sugar Loaf and Louvre Terminals.*

In some preliminary memoranda made by Mr. Field in 1897, as to Sugar Loaf and Louvre Terminals, the following notes appear with reference to the experiments:—

19th April.—The length of the side (as long as it is more than 2½ inches) and the size of the top do not much affect the efficiency.

Down-draught.—No *plain* Sugar Loaf can be constructed which will be proof against down-blow and fairly good against up-blow. The nearest approach with plain pipe is when the top is 65 per cent. of annular space at bottom, in which case it will be proof against down-blow as long as angle does not exceed 50°, and against up-blow as long as angle does not exceed 38° (40° ?). When area of top is 50 per cent. of annular space it is completely proof against down-blow, and this can easily be made proof against up-blow by a ring fitted to the pipe below.

The following conclusions as to Sugar Loaf Terminals were drawn on 14th October, 1896, from a study of down-draught experiments:—

In order to prevent down-draught, Position A at 60° Ratio $\frac{\text{Col. 3}^{*}}{\text{Col. 4}}$ must not be *more* than ·50 (·53 ?), unless Sugar Loaf is a considerable height above pipe. (This is the reason of down-draught with diverging tube.)

In order to prevent down-draught, Position B at 40° Ratio $\frac{\text{Col. 3}}{\text{Col. 4}}$ must not be *less* than ·63, unless Sugar Loaf is a considerable height above pipe.

* Col. 3 = area of top of Sugar Loaf; Col. 4 = area of annular space at bottom of Sugar Loaf.

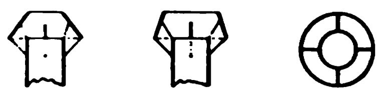
It follows that Sugar Loaf cannot be made down-draught proof at 60° Position A and 40° Position B, unless Sugar Loaf is considerable height above pipe.

The Sugar Loaf with top 4½ inches diameter, bottom 7½ inches, and side 18 inches long, is decidedly worse for Position A than that with side 9 inches long, and no better for Position B.

Louvres.

Effect of lengthening Conical Louvres. 10th May, 1897.

The lengthening of these conical louvres apparently affects the efficiency when the wind blows between the feathers more than it does when it blows against them, thus exactly reversing the action in the case of cylinder louvres. In the case of between feathers also, lengthening improves the efficiency instead of diminishing it as in the case of cylinders. (Report, Table XXVII., pp. 349).



Upcast. Four Feathers.—The height of the louvre with 3-inch pipe should not be more than 3 inches.

N.B.—The lengthening of the cylinder louvres especially affects the efficiency when the wind blows *against* the feathers. (This only applies to cylinders). With short cylinder Between is better than Against. With long cylinder Between is worse than Against.

In order to get greatest efficiency two conditions seem to be necessary. (1) Area of top should be about equal to annular space at bottom; (2) Area of annular space at bottom should be 4 or 4½ times area of pipe or diverging tube.

It is a *disadvantage* to make the louvre too large.

If above conditions are adhered to, but not otherwise, a 4½ inch diverging tube gives about 6 per cent. better efficiency than a plain pipe.

Four Feathers.—When the top of the louvre is reduced (as it must be to prevent down-draught from down-blow, see below), the efficiency is greatly reduced, and in this case also the reduction is much greater with wind blowing *against* the feathers than with wind blowing between.

Down-draught.—A louvre with top about same area as annular space at bottom is subject to strong down-draught from down-blow. In order to prevent this, area at top must be reduced to 30 per cent. (or slightly less) of annular space, when it will be down-draught-proof with down-blow, and only subject to down-draught with up-blow when angle more than 45° (?). The efficiency with 6-inch bottom will be only 1·08 (?).

Conical Louvres: Four Feathers. 12th May 1897.

Results of down-draught tests, 11th May, 1897, on louvres 7-inch diameter bottom, to a certain extent upset experiments with louvres 6-inch diameter bottom made on 12th April, 1897, and show that with $\frac{\text{Top of louvre}}{\text{Annular space at bottom}} = \cdot 23$, 6-inch bottom is not proof from down-blow at 60° angle. Any ratio smaller than ·23 is quite out of the question, as the efficiency would be so very low. The small-top louvre cannot, therefore, be made a first-class cowl as regards down-draught without covering, and if covering has to be adopted it will be better to use a large-top louvre, as the efficiency will be much better. It is, therefore, not worth spending time on small-topped louvres in trying to effect small improvements in them by increasing the number of feathers or putting on fillets.

On the other hand, $\frac{\text{Top of louvre}}{\text{Annular space at bottom}} = \cdot 28$ will be down-draught-proof from down-blow with angle 54°, and from down-draught from up-blow at an angle of nearly 50°, so that it is a fairly good working and simple terminal with four feathers.

Down-draught. 13th May, 1897.

Comparison of 3-feathered louvres with 4-feathered louvres.—A comparison of the down-draught curves for 3-feathered louvres, with down-draught curves for 4-feathered louvres, shows that with $\frac{\text{Top of louvre}}{\text{Annular space at bottom}} =$ ·50 and above, the curves for the 3- and 4-feathered louvres appear to agree. On the other hand, with $\frac{\text{Top of louvre}}{\text{Annular space at bottom}} =$ less than ·50 the curves differ, especially the up-blow; the 3-feathered louvres being rather better than the 4-feathered louvres with down-blow, and much worse than 4-feathered louvres with up-blow.

LOUVRES. 6th July, 1897.

Experiments of 6th May show that with a small-topped louvre wind blowing against feathers, the best result is got when the louvre is 1½ ins. deep, and the worst when 3 ins. deep. When blowing between feathers the best result is when louvre is 3 ins. deep, and worst when 1½ ins. deep.

The above is confirmed by experiments of 21st May, 1897, when with wind blowing against feathers the best result is obtained at 2½ ins. deep and worst at 4 ins. deep.

With wind blowing between feathers the depths apparently make not much difference.

Large Topped Louvres.

Wind blowing against feathers, practically no difference between 1½ ins. and 3 ins. deep.

Wind blowing between feathers, practically no difference between 1½ ins. and 3 ins. deep.

Experiments of 26th March, 1897, seem to show, by comparing against and between, that top of louvre must be large enough to take discharge from pipe plus the entry at bottom of louvre; also that a louvre is spoilt by making it too large.

HEIGHT OF LOUVRES. 14th August, 1897.

Index Number of Experiment.	
5528 to 5542.	3 *Feathers.*—With 4½-in. top, 6-in. bottom over 3-in. pipe, height of louvre between 1½ ins. and 6 ins. makes no difference in efficiency.
5968 to 5979.	4 *Feathers.*—With 5¼-in. top, 6-in. bottom, height of louvre between 1½ ins. and 3 ins. makes no difference.
5824 to 5827.	4 *Feathers.*—With 6-in. cylinder efficiency diminishes when height increased from 3 ins. to 6 ins.
6012 to 6019.	4 *Feathers.*—With 7¾-in. top, 9-in. bottom, over 4½-in. and 18-in. diverging tube 4½ ins. high, is not so good as 3 ins. high.
6020 to 6927.	4 *Feathers.*—With 9-in. cylinder over 4½-in. and 18-in. diverging tube 4½ ins. high is not quite so good as 3 ins. high.

PART II.—STANDARD CURVES.

THE PREPARATION OF STANDARD CURVES FOR DETERMINING THE FLOW OF AIR THROUGH A PIPE, FROM READINGS OF AN AIR METER PLACED IN THE PIPE.

THE method adopted by the Committee for their work in comparing Cowls was to ascertain by means of the readings of air meters the flow up vertical tubes surmounted by the cowls in question. The first part of the investigation was, therefore, to test the readings of the air meters employed, in order that the results derived therefrom might be made really comparable one with another.

Corrections for these instruments are generally given by the makers. It is usual to adopt a single number, to be added to the readings of the instrument, intended to represent the allowance that must be made for friction, etc. The following series of corrections for the air meters used by the Committee (Table I.) was furnished by Mr. Lowne, the maker. The corrections were apparently determined by mounting the instrument at the extremity of the arm of a whirling machine, and comparing the length of the path described by the instrument on the whirler with the corresponding indication of the instrument itself. Specimens of the experiments upon which the corrections were based are given in Table II., p. 231.

At the Kew Observatory (now the National Physical Laboratory) tests of these instruments are carried out in a similar manner; and in response to a request from the Editor, Dr. Chree, the Superintendent of the Observatory Department, kindly supplied the following account of the general results of the tests of air meters at Kew, with a note of the test of one of the meters belonging to the Cowl Committee.

"I have looked into some of the more recent data obtained in the "verification of air-meters. Of late years the practice has been to take "as the independent variable the velocity recorded by the meter, and to "chronicle the percentages of the true velocities, as deduced from the "counted revolutions of the revolving arm. The observer really draws a "curve to fit the observed values, and deduces therefrom figures answering "to velocities of 30, 40, 50, or other round number. For a very exact "inquiry it would be better to have recourse to the actual observation "data, but I have not thought it necessary to do this. A glance at the "data shows that at high velocities the ratio borne by the recorded "velocity to the true velocity approaches an asymptotic value, and at

Table I.—3-in. Air Meters.

Table of Corrections for Air Meters.

Taken from separate Tables specially prepared by maker on printed forms.

No. 619. The fan begins to move at about 58 feet per minute.		No. 611. The fan begins to move at about 58 feet per minute.		No. 620. The fan begins to move at 60 feet per minute.		No. 446. The fan begins to move at 60 feet per minute.	
Velocity shown by meter per minute.	Correction for velocity shown by meter per minute.	Velocity shown by meter per minute.	Correction for velocity shown by meter per minute.	Velocity shown by meter per minute.	Correction for velocity shown by meter per minute.	Velocity shown by meter per minute.	Correction for velocity shown by meter per minute.
Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
20	+ 53	20	+ 53	20	+ 57	20	+ 57
40	+ 50	40	+ 50	40	+ 54	40	+ 56
60	+ 48	60	+ 48	60	+ 52	60	+ 54
80	+ 46	80	+ 46	80	+ 49	80	+ 52
100	+ 44	100	+ 44	100	+ 47	100	+ 51
120		120		120		120	
140		140		140		140	
160		160		160		160	
180		180		180		180	
200	+ 41	200	+ 41	200	+ 37	200	+ 47
220		220		220		220	
240		240		240		240	
260		260		260		260	
280		280		280		280	
300	+ 39	300	+ 39	300	+ 33	300	+ 46
320		320		320		and above	
340		340		340			
360		360		360			
380		380		380			
400	+ 38	400	+ 38	400	+ 28		
420		420		420			
440		440		440			
460		460		460			
480		480		480			
500	+ 37	500	+ 37	500	+ 27		
520		520		520			
540		540		540			
560		560		560			
580		580		580			
600	+ 36	600	+ 36	600	+ 26		
and above		and above		and above			
	Corrections for Air Meters pasted by maker into box.						
Add per minute to the observed reading of the Air Meters.	40		40		30		46

NOTE.—Each instrument is now regulated so as to reduce the correction to a constant quantity per minute, which must be added as in the example given.

Table II.—3-in. Air Meters.

Table of Experiments made with the Whirling Machine at Mr. Lowne's workshop, Leicester House, Finchley, 14th September, 1878.
(*Book* AA_4, *page* 15.)

Instrument.			Whirler.			
Description of instrument.	Interval in minutes.	Register per minute in feet.	Distance of instrument from axis in feet.	Distance travelled each revolution in feet.	Number of revolutions.	Feet per minute.
Three-Inch Air	1	261	3·98	25	12	300
Meter, No. 446.	1	258	3·98	25	12	300
	1	561	3·98	25	24	600
	1	561	3·98	25	24	600
Three-Inch Air	1	572	3·98	25	24	600
Meter, No. 619.	1	263	3·98	25	12	300
	1	263	3·98	25	12	300
Three-Inch Air	1	260	3·98	25	12	300
Meter, No. 611.	1	570	3·98	25	24	600
	1	566	3·98	25	24	600

"velocities above 500 feet per minute the variation in the ratio is small. "It also appears that at the higher velocities the average air-meter "(without any addition of 30 feet per minute) recorded somewhat too "much. [I am not prepared, without more minute investigation, to "maintain that this may not be due, in whole or part, to the testing "conditions.] On an average 2,000 feet was recorded, when the supposed "true velocity was 1,916 feet; *i.e.*, the meter recorded 104·4 per cent. of "the true velocity. Amongst the air-meters whose records I examined, "the extremes were 86 per cent. and 122 per cent. To put all the meters "on the same footing I first assumed that each at 2,000 feet per minute "gave the true velocity. For instance, if one really recorded 122 per "cent. of the true velocity when recording 2,000 feet per minute, I "divided the percentage given for each lower velocity by 122, and then "took the mean of the results thus found; then converting the per-"centages into absolute velocities I found the following results (velocities "in feet per minute):—

Velocities by meter.	40	50	60	70	80	90	100	120	150	200	250	300	400	500	600	1,000	1,500
True velocities.	83	88	94	104	118	127	130	160	179	225	281	326	426	520	621	1,016	1,508
Errors (all negative).	43	38	34	34	38	37	30	40	29	25	31	26	26	20	21	16	8

"If, now, we apply a correction of + 30 according
"instructions, we are left with the following errors:—

−13 −8 −4 −4 −8 −7 0 −10 +1 +5 −1 +4 +4 +10

"Perhaps the more natural (though less instructive) way
"figures would be to compare the recorded and true veloc
"meter separately, without taking account of the size of t
"ratio at high velocities. I have not taken the trouble to d
"but have made a calculation coming to pretty much the
"employing the mean percentages, assuming that they answ
"meter recording 4·4 per cent. too high when recording 2,
"minute. In this way we get the following figures:—

Velocity by meter.	40	50	60	70	80	90	100	120	150	200	250	300	400	500	600	1,
Adding 30.	70	80	90	100	110	120	130	150	180	230	280	330	430	530	630	1,
True Velocity.	80	84	90	100	113	122	125	153	172	216	269	312	408	498	595	[illegible]
Error.	−10	−4	0	0	−3	−2	+5	−3	+8	+14	+11	+18	+22	+32	+35	+

"In all, thirty meters were included, but at many points
"data for only a minority of these, most being compared at o
"eight velocities. Thus the results are imperfectly smooth.
"or eight were 'Biram' anemometers; these gave, if anyth
"higher percentages than the 'ordinary,' but nothing to be sur
"were in three cases data answering to a recorded velocity of
"minute, when percentages are given as 32, 45, and 27 r
"clearly friction comes in more largely at such low velo
"according to the correction of 30 feet per minute. Mr. Ro
"4-inch air-meter was last tested here some seven or eight
"with the following results:—

Rate by meter.	60	70	80	100	250	300	600	1,000	1,5
Percentage of true velocity.	68	76	78	87	100	103	106	109	11

"This, I understand, was after it had been supplied with li
"than it originally possessed."

In this connexion it should be noticed that an air meter ma
in two very distinct ways: first it may be freely exposed to a
air that is quite unconfined, or limited only by a large air gra
this case, the presence of the meter offers no appreciable obst
the general flow of air through the grating, of which it only
small part, and what the air meter is intended to record is not t
air actually passing through the ring of the meter, but what w

through the corresponding space if it were not obstructed by the meter. Hence the appropriate correction to the dial readings should compensate for the obstruction which the meter offers to the flow of air through its own ring. The second way of using the instrument is to place it within a tube of the same area approximately as the ring of the meter, and in this case the meter offers a resistance to the flow of air through the tube, and seriously affects the flow, in consequence of the fact that the ring and the boss of the whirler occupy an appreciable portion of the area of the tube through which the air flows. Hence corrections based upon measurements on a whirler and suitable for the first method of using a meter are not by any means suitable for the instrument used in the second manner.

The difference in the numbers obtained with an air meter, according as it is used in the one manner or the other, may be illustrated by the numbers in Table III. exhibiting the results obtained, probably by Mr. Dines at Hersham in 1888. In these experiments the run of a whirling machine is compared with the readings of the anemometer carried on the whirler, corrected first by the corrections specially drawn up from the experiments with tubes and gasholders (column 12 of the table), and secondly, with the maker's corrections (column 13). It will be noticed that the smaller air meters give readings agreeing with that of the whirler within 10 per cent. at the most where the maker's corrections are taken, and 18 per cent. is the smallest difference when the curves constructed for air meters in tubes are used to interpret the readings.

The Cowl Committee used the meters after the second method, and rightly thought it desirable to carry out special tests of the Air Meters for their investigations. They based their tests upon the records of the Air Meters placed in tubes along which known volumes of air were passed from, or into, graduated gas-holders.

From experiments of this description a diagram of curves, known as the "Standard Curves" (which is reproduced in Diagram 5, page 235) was constructed for the smaller Air Meters, and another corresponding Diagram 6 (reproduced on page 236), for the larger ones. On these curves the base was "Register feet per minute," that is, the number of feet run recorded on the dial of the instrument; and the vertical was "Actual velocity feet per minute through inside ring of Air Meter." By their means the readings of any one of the Air Meters can be reduced to actual velocity of air through the ring of the Air Meter, and then by calculation to actual velocity along the tubes. These curves represent the results of a very large number of experiments which may be grouped as follows:—

Table III.—Experiments on Air Meters at Hersham, 1888.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Instrument					Whirler.					Instrument compared with Whirler.					
Description of Instrument.	Time experiment started. Hrs. Mins.	Interval in minutes.	Register	Register per minute.	Distance of Instrument from axis. Feet.	Distance travelled each revolution	Revolutions during interval.	Feet travelled during interval.	Feet per minute.	Col. 10 ÷ Col. 5.	Velocity of Instrument by R.F. curve. (Standard curve.)	Velocity of Instrument by maker's correction.	Col. 10 ÷ Col. 13.	Col. 10 ÷ Col. 14.	
May 19th, 1888.															
Three Inch Air Meter No. **446.**	4—44	5	3,409	682	18.0	113.1	31	3,506	701	1·028	...	738	...	·950	Add 46 to velocity shown
	5—8	5	3,228	646	18.0	113.1	28	3,167	633	·980	...	692	...	·915	by Meter per minute.
May 26th, 1888.															
Three Inch Air Meter No. **619.** Tubes on	5—24	10	8,611	861	18.0	113.1	69	7,804	780	·906	643	...	1·213		
	5—44	10	8,104	810	18.0	113.1	66	7,465	747	·922	605	...	1·235		
	6—2	12	9,506	792	18.0	113.1	77	8,709	726	·916	592	...	1·226		
Tubes off	6—44	10	8,023	802	18.0	113.1	71	8,030	803	1·001	...	838	...	·958	Add 36 to velocity shown
	7—11	10	6,788	678	18.0	113.1	61	6,899	690	1·018	...	714	...	·966	by Meter per minute.
Three Inch Air Meter No. **620.** Tubes on	5—24	10	4,402	440	9.0	56.55	69	3,902	390	·886	330	...	1·182		
	5—44	10	4,193	419	9.0	56.55	66	3,732	373	·890	315	...	1·184		
	6—2	12	4,898	408	9.0	56.55	77	4,354	363	·889	307	...	1·182		[by Meter per minute.
Tubes off	6—44	10	4,148	414	9.0	56.55	71	4,015	402	·971	...	442	...	·910	Add 28 to velocity shown
	7—11	10	3,406	340	9.0	56.55	61	3,450	345	1·015	...	371	...	·930	Add 31 to velocity shown
Six Inch Air Meter No. **673.**	5—24	10	14,248	1,424	26.9	169.02	69	11,662	1,166	·819	1,107	...	1·053		[by Meter per minute.

Standard Curves for correcting 3-inch Air Meters.

(Revised Mar. 1st, 1894. See also Table 5.)

Corrections for converting Register into actual Velocity through ring of Air Meter, plotted from Draw In Experiments made at Cannon Row in June, 1884.

The Experiments were all made in the same month and under uniform conditions, on 2·7-in. Air Meters fixed between two Tubes 2·7-in. in Diameter (see Sketch below).

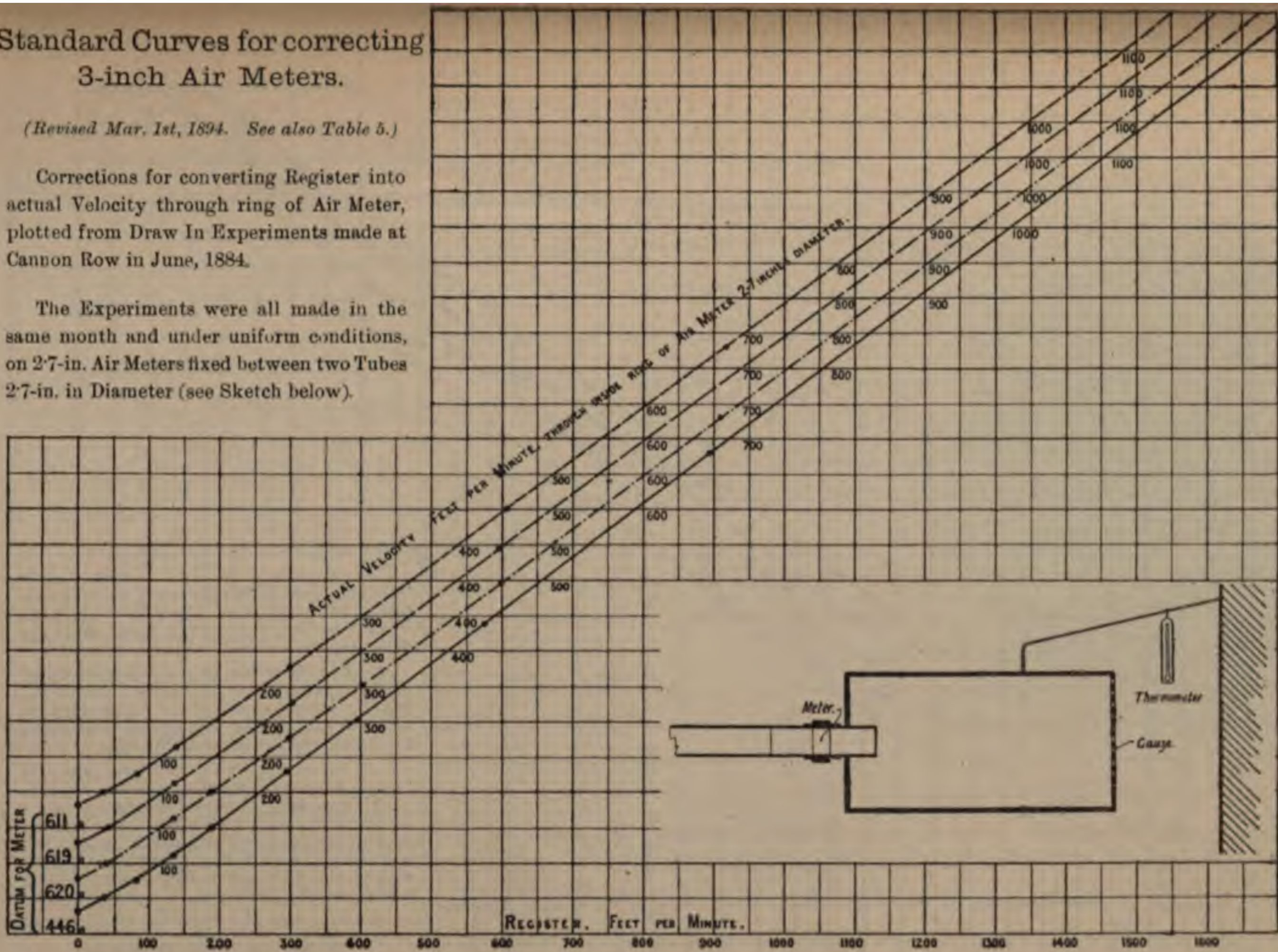


Diagram 5.

Diagram 6.

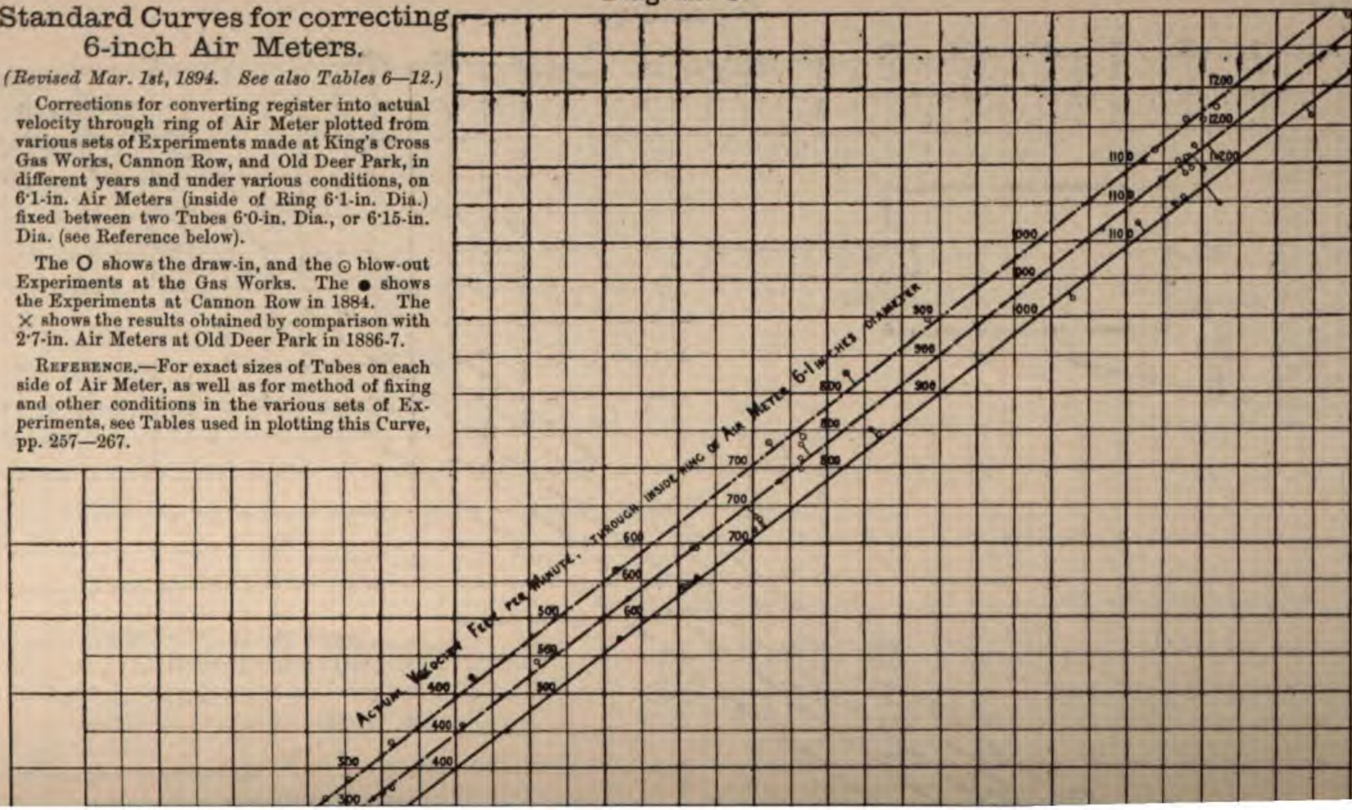
Standard Curves for correcting 6-inch Air Meters.

(Revised Mar. 1st, 1894. See also Tables 6—12.)

Corrections for converting register into actual velocity through ring of Air Meter plotted from various sets of Experiments made at King's Cross Gas Works, Cannon Row, and Old Deer Park, in different years and under various conditions, on 6·1-in. Air Meters (inside of Ring 6·1-in. Dia.) fixed between two Tubes 6·0-in. Dia., or 6·15-in. Dia. (see Reference below).

The O shows the draw-in, and the ⊙ blow-out Experiments at the Gas Works. The ● shows the Experiments at Cannon Row in 1884. The × shows the results obtained by comparison with 2·7-in. Air Meters at Old Deer Park in 1886-7.

Reference.—For exact sizes of Tubes on each side of Air Meter, as well as for method of fixing and other conditions in the various sets of Experiments, see Tables used in plotting this Curve, pp. 257—267.



(1) *For 2·7-inch Meters.*—In 1884 experiments were made at Mr. Field's office in Cannon Row with a gasholder of 11 cubic feet capacity, by drawing in and expelling air through the smaller Air Meters fixed in a tube communicating with the holder. Experiments in which air was drawn in are referred to hereafter as "Draw in" experiments, and those in which air was expelled as "Blow out" experiments. In the case of the smaller air meters, only the "Draw in" experiments were used for constructing the curve represented on Diagram 5, p. 235.

Diagram 7.

(2) *For 6·1-inch Meters.*—In 1880–81 experiments were made at King's Cross Gas Works with a gas holder of 120 cubic feet capacity, by drawing in and expelling air through the larger (6·1-inch) air meters fixed in a tube communicating with the holder. In this case both "Draw in" and "Blow out" experiments were made use of for constructing the curve (Diagram 6).

In 1884 special temperature experiments were made at Cannon Row by drawing in air through the larger air meters attached by means of a converging tube to the outlet of the small holder.

(3) *To obtain indirectly accurate curves for the 6·1-inch meters.*—In 1886–87 experiments for comparing the readings of the larger and smaller air meters were made at a Hut in the Old Deer Park, Richmond, by observing the effect produced upon the registering dial by the natural wind blowing over the open end of a tube in which the smaller air meter was fixed above the larger one. The passage of the air from the aperture below was directed to the smaller aperture above by means of a converging tube. The superposition of the smaller air meter is shown on Diagram 7.

Many other experiments were made for the purpose of testing the smaller meters at Messrs. Sugg's Works in 1879–80, and 1881–2, but as the results obtained from them were not used for the final curves, they will be referred to in what follows as preliminary experiments.

Preparation of Standard Curves for Converting Run into Actual Velocity, 2·7-inch Air Me

The 2·7-inch Air Meters, used for the Cowl experiments in 1878 from Mr. Lowne, anemometer maker. They were the following manner (see Diagram 8, facing page 240):—The on jewelled centre midway in a brass tube 2·7 inches in diamet in length. This fan had 8 metal blades, the inner parts of lapped the centre boss to the extent of $\frac{1}{20}$ of an inch. The fixed in position by three brass stays $\frac{1}{20}$ of an inch wide. T the fans was conveyed to the dial by means of the mechanism i box, which was supported by a tube 2·7-inch diameter, encas necting rod. The mechanism in the box consisted of the vertic fans, the upper portion of which was an endless screw, which its motion to a cog-wheel on the horizontal connecting bar. disconnected the worm-wheel from the spiral on the axis an worm-wheel in or out of gear.

A number of measurements were taken, probably in 1889, the run of the vanes of the meters compared with the linear the dial. From these experiments it appears that the recorde would correspond to the run of a point intermediate between t a vane and its outer extremity. The particulars of the diffe are as follows :—

No. of Meter.	Diameter of ring enclosing fan-wheel.	Diameter of circle which gives recorded linear run.
	In.	In.
446	2·70	2·25
611	2·70	2·21
619	2·70	2·27
620	2·70	2·27

The diameter of the fan between the centres of opposi 1·85 inches.

Preliminary Experiments.—A long series of preliminary e on the 2·7-inch meters were made at Messrs. Sugg's Work Street, Westminster, in 1879–80, by *blowing out* a known qua from a 10 ft. experimental gas-holder through a 3-inch tube, of which the Air Meter was fixed, and then calculating the air transmitted through the meter, and comparing this with the product of the velocity registered by the instrument and the the tube. The gasholder was adjusted by weights over a wh a regular flow of air could be expelled. To the outlet pipe

three stopcocks, two above and one below. A pipe, two inches in diameter, was fixed to the outlet at the lower stopcock, bent into a vertical position and then carried horizontally along for a short distance, when it was attached by a cone 9 inches in length to a horizontal tube 2¾ inches in diameter. The Air Meter to be tested was fixed to this horizontal tube, and at the expiration of each minute or half minute (the usual duration of these experiments) the dial reading was noted. Curtains were hung on two sides of the holder to keep away draughts. A sketch of the gasholder and connections is given in the illustration of the candle flame experiments (Diagram 29, p. 292).

In carrying out these first experiments it was first assumed that the usual mode of correction with the numbers supplied by the makers was substantially right, but this assumption gave erroneous results for air meters fixed in tubes (see p. 232). The velocity was then treated as referring to the whole area of the guard-ring of the instrument, when it was found that the instrument registered more instead of less than the results thus obtained, and the correction varied enormously with different velocities instead of being constant. On the other hand, it was found that if the clear annular space of the meter (deducting the centre boss and other obstructions) was used for calculating the velocity, something more nearly approaching the maker's results could be obtained. In these first experiments, therefore, the velocities were calculated by taking the clear annular space of the meter, giving 34·7 lineal feet for 1 cubic foot, and the results were reduced by taking the difference between the calculated (gas-holder) velocity and the calculations from the register of the air meter in feet per minute. Subsequently, however, reductions were made in which no deduction was made for the boss, but the full area was used giving 25·15 lineal feet for 1 cubic foot. The results of these experiments were plotted on the following curves. (Diagrams 9, 10, 11, and 12, pp. 240 to 243.)

These curves show very considerable irregularities, and ultimately, as will be seen, the results were not used in compiling the final curves, but without further investigating the causes of the irregularities the Committee proceeded in 1880–1881 to make experiments upon the larger meters with a large gasholder at King's Cross Gas Works. These gave even more unsatisfactory results than the experiments with the smaller meters, and the Committee had to report that the use of the larger meters should be abandoned, and that for the smaller meters sufficiently accurate results could not be obtained without further investigation of their action.

Accordingly, experiments at Messrs. Sugg's Works were taken up again in 1881–2, from which it became apparent that irregularities similar to those which appeared in the results could be accounted for by the effect of draught, differences of temperature, and other small disturbing causes, of which no account had been taken in the original experiment. In order to have the conditions of the experiments more directly under control, a special arrangement was set up in Mr. Field's office in Cannon Row in 1884, where, under conditions for uniform testing with "*draw in*"

Curve plotted in 1893 *from* "*Blow Out*" *experiments at Sugg's Works,* 1879–80, *on* 2·7-*in. Air Meters. Each dot represents an average of about* 3 *experiments.*

Meter No. 446.

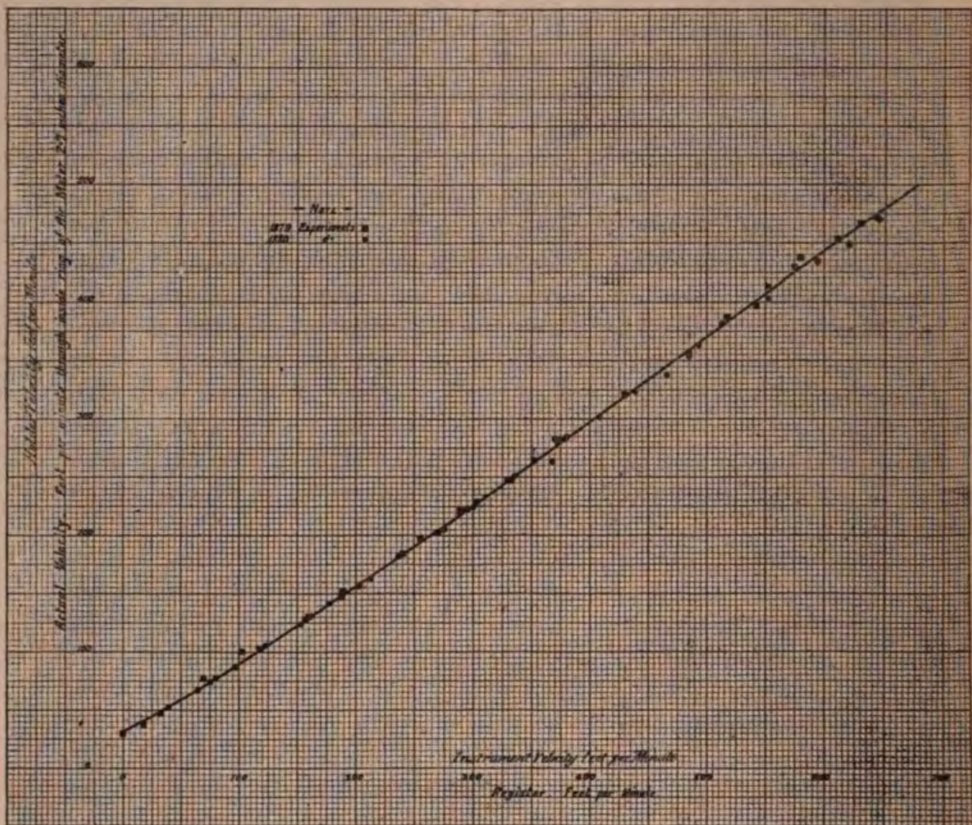
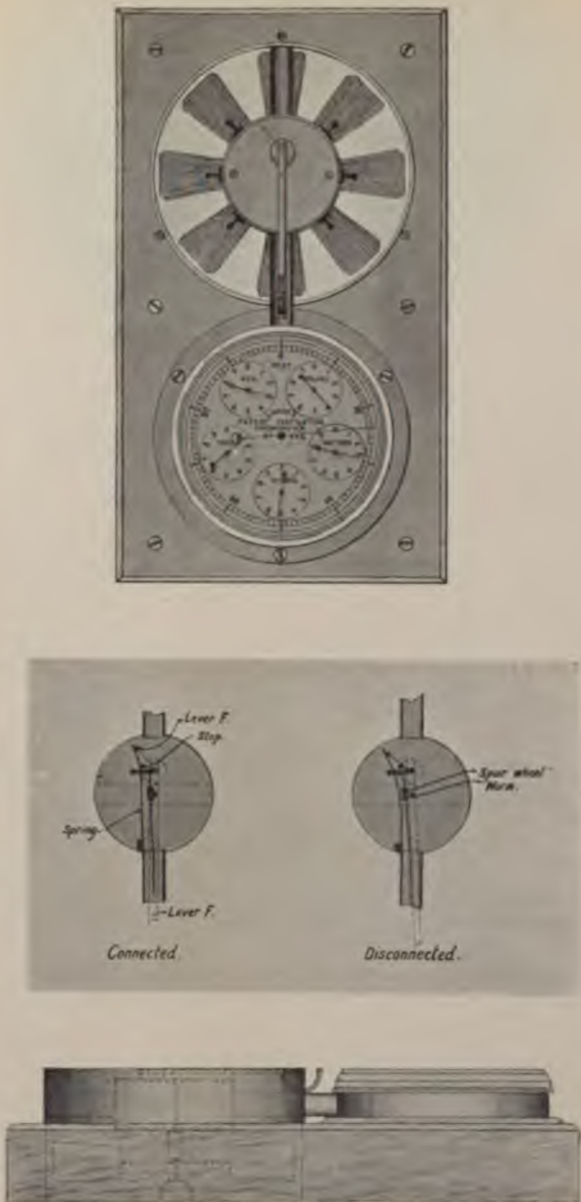


Diagram 9.

Diagram 8.



3 INCH AIR METER.

Curve plotted in 1893 *from* "*Blow Out*" *experiments at Sugg's Works,* 1879–80, *on* 2·7-*in. Air Meters. Each dot represents an average of about* 3 *experiments.*

METER No. 611.

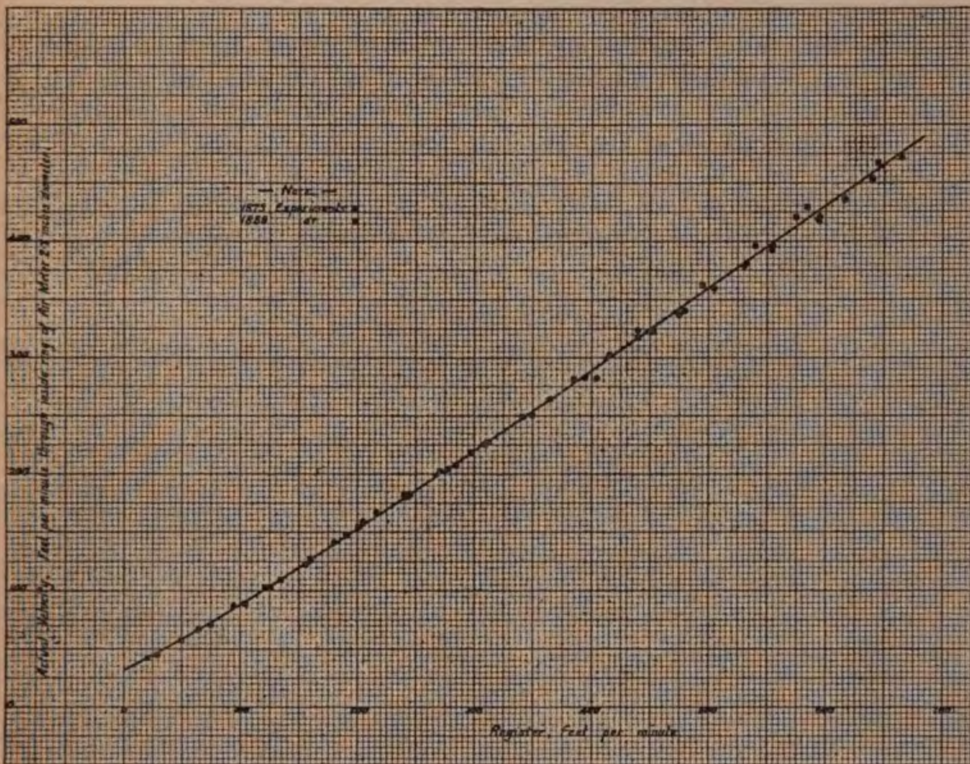


Diagram 10.

experiments, a consistent reading of 292·1 on the meter for 9 cubic feet of the gasholder, or 226·8 lineal feet through the full orifice of the ring of the meter was obtained. This result which is called the "standard draw in register" for Meter No. 446, was used as a basis in discussing the second series of experiments at Messrs. Sugg's Works (1881–2), as well as those at Cannon Row (1884). The two may almost be regarded as one series. There was, however, as a matter of fact, a considerable interval of time between them. The contributions to the final results of the two sets of experiments are indicated in what follows.

The experiments at Messrs. Sugg's Works in 1881-82 supplied a

number of measurements under very varied conditions. They included a few "blow out" as well as a large number of "draw in" experiments, and also experiments when the tube was covered with a cap, or otherwise partially blocked by some special contrivance. Using the "standard draw in register" subsequently determined as the basis of comparison, the results obtained may be described as follows.

In the case of experiments under ordinary conditions the average register of 242 experiments was 0·7 per cent. above the standard, whereas the average register of 279 experiments under special conditions (such as blowing across the mouth of the tube with bellows, placing a cap in

Curve plotted in 1893 *from* "*Blow Out*" *experiments at Sugg's Works,* 1879–80, *on* 2·7-*in. Air Meters. Each dot represents an average of about* 3 *experiments.*

METER No. 619.

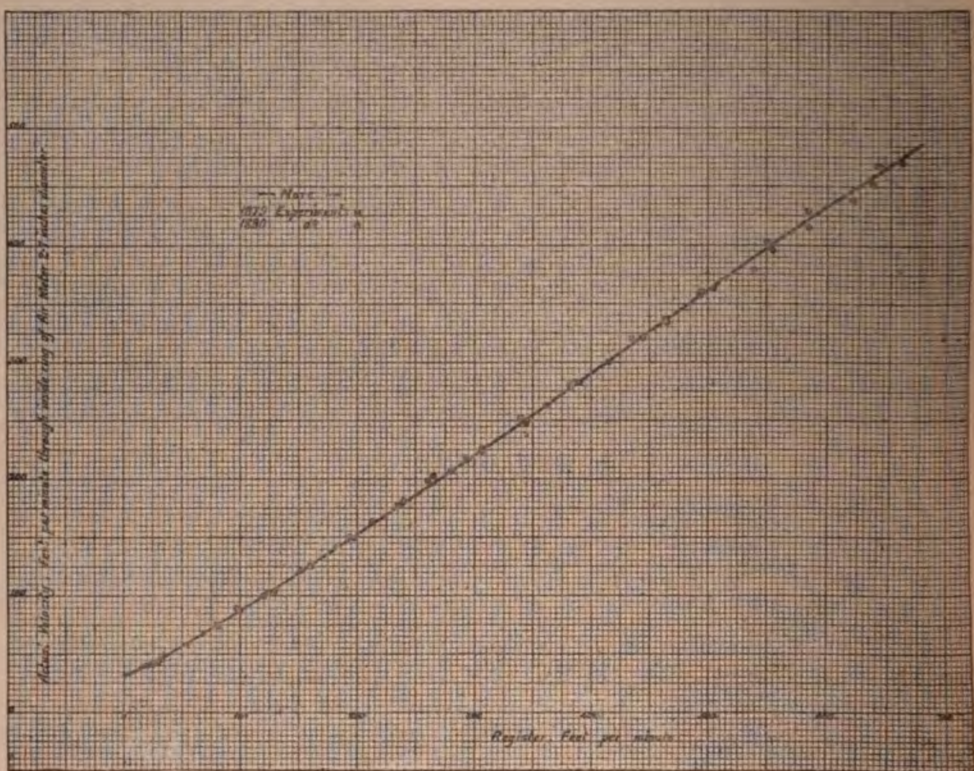


Diagram II.

Curve plotted in 1893 *from* "*Blow Out*" *experiments at Sugg's Works,* 1879–80, *on* 2·7-*in. Air Meters. Each dot represents an average of about* 3 *experiments.*

METER No. 620.

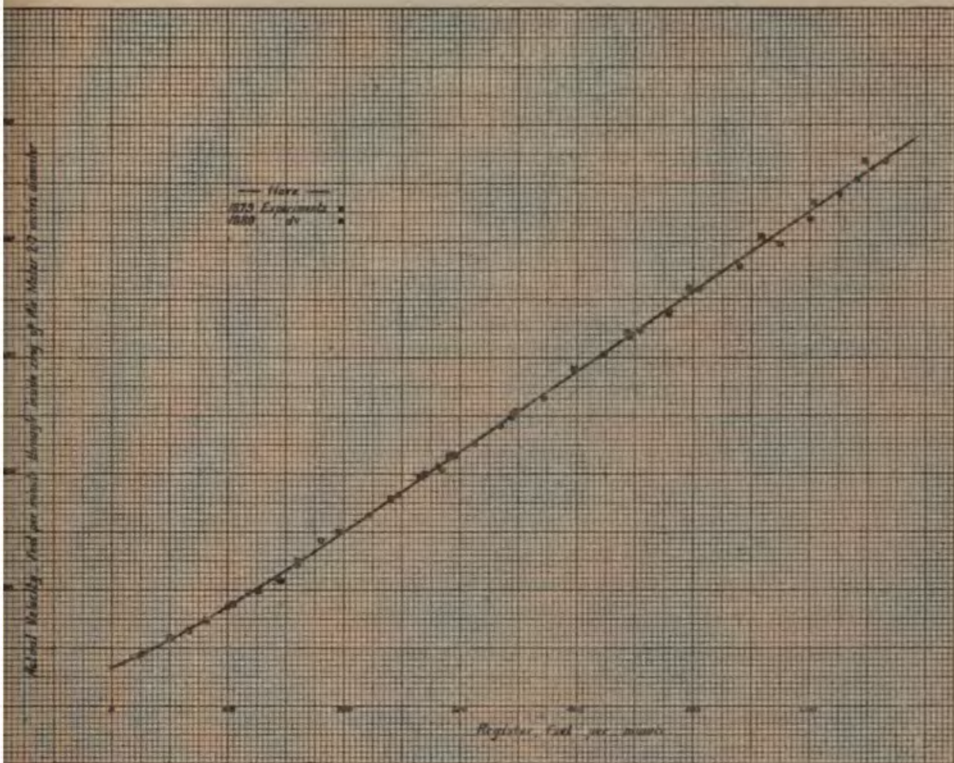


Diagram 12.

front, &c.), was as much as 2·2 per cent. above the standard. Experiments were made to show the effect of blowing on registration in the case of "Draw In" experiments and of "Blow Out" experiments, 9 cubic feet of air (= 226·8 lineal feet through the tube) being drawn into or blown out of the holder in each experiment. The results of the experiments* were averaged, and maximum and minimum registrations tabulated. These showed that in the case of "Draw In" experiments the

* This refers to experiments at Sugg's Works, 1881–2, the details of which are preserved, but are not used in the final results.

percentage range was 5·8 without blowing and 7·1 with blowing, whereas in the case of "Blow Out" experiments the range of difference without blowing was 2·4 and with blowing only 2·2. Further, a series of "Draw In" experiments was made to ascertain the effect of placing a loose cap 7¼ inch diameter over the end of the 4-inch delivery tube (1) when the entrance to the cap was left free, but the cap moved so as to place the tube in different positions in the cap, and (2) when the entrance to the cap was partially blocked in different ways, and the cap moved so as to place the tube in different positions with regard to it. In these experiments 9 cubic feet (=226·8 lineal feet) of air were drawn into the holder, and tubes either 4 inches or 13 inches in length were adjusted in front of the air meter. In the case of 4-inch tubes, the register of the air meter varied by the range of 12·3 per cent. when cap was not blocked, and by 16·4 per cent. when cap was blocked; in the case of 13-inch tubes in front, the range was 10 per cent. when the cap was not blocked, and 21·9 per cent. when blocked. Some experiments were also tried to ascertain the effect of caps concentric and co-axial with the tube. These experiments showed that caps such as those used did not prevent the influence of draught, and did not make the readings of the air meters regular.

Experiments were also tried with fanning so as to produce artificial draughts in front of the instrument, also with paper tubes turned at different angles so as to direct the air in different directions into the meter, but no conclusive results were obtained in this way.

In order to ascertain whether the irregularities in the results of the experiments at Messrs. Sugg's Works were due to the defects in the air-meters, or to defects in the method of testing them, an experimental gasholder was specially fixed in one of Mr. Rogers Field's rooms at 5, Cannon Row, Westminster, in April 1884. The apparatus and arrangements were thus much more under control, especially as to draughts and as to heating up and cooling down the air in the room and the water in the holder, so that more careful experiments could be tried than was possible in the large workshop at Messrs. Sugg's Works.

The gasholder for the tests at Cannon Row, which was 11 cubic feet in capacity, was made by Messrs. Parkinson of Westminster, and consisted of a cast iron tank containing water, and a holder which moved vertically up and down on supporting columns. To ensure regularity of movement the holder was fitted with a cycloidal lever carrying a weight. A 2-inch pipe communicated with the holder and had a stopcock. From here a zinc coning piece, 3 feet long, was attached to a short brass tube fitting on to the 2·7-inch diameter ring of the air meter. In order to admit the air

to the instrument equably and without draught, a box 1 foot 3 inches square and 2 feet 6 inches long with fine gauze screen on the open end was fitted around the second small brass tube fixed to the side of the instrument furthest from the holder. The box and instrument were supported on a wooden table, and a curtain placed over the box. The gauze on the end of the box was 11 inches away from the wall. Displacement of the water by immersion of the holder was allowed for in the rating of the holder, *i.e.*, the drawing of the scale so that 9 cubic feet exactly was drawn in in the "Draw In" experiments, and 9 cubic feet exactly was blown out in the "Blow Out" experiments.

After preliminary trials regular "Draw In" experiments at Cannon Row began in June, 1884, and were made under uniform conditions, with the four 3-inch air meters (2·7 in. internal diameter), in order to plot a curve for converting register in feet per minute into actual velocity through the ring of the air meter.

To avoid draughts the box with gauze side fixed on the end of the tube was used. In order to correct the register of the air meters for slight differences of temperature special experiments were made on June 6th and 7th, 1884, with Air Meter No. 446, by artificially heating the room and cooling the water in the gasholder, or vice versa. In this way differences of temperature amounting to 24·4° were obtained between the water and the room. When the room was hotter than the water, it was found that the registration both for "Draw In" and "Blow Out" experiments was greater than when the room was at the same temperature as the water. The amount of the difference in the registration was less in the "Blow Out" experiments than in the "Draw In"; the following table is given as an example, for the same volume of air:—

Temperature of Room below that of Water.	Meter Reading.	Temperature of Room above that of Water.	Meter Reading.	Difference.
"Draw In" Experiments. 9°	287·4	15°	301·4	14·0
"Blow Out" Experiments. 9°	295·6	15°	302·9	7·3

The difference in the readings also depended on the rate of flow of air into the holder, being greater when the speed was slow, and less when the speed was rapid. Thus when the 9 cubic feet passed in about half a

minute, the registration varied from 298·0 feet to 303·6 f
when 9 cubic feet passed in about one minute, the registratio
304 feet to 287·2 feet (16·8 feet), and when in about two
registration varied from 298 feet to 266 feet (32·0 feet).

The explanation of the effect caused by the difference
temperature of the room and that of the water was clearly as f
the room was warmer than the water, the air drawn into th
cooled and occupied less space, so that more than 9 cubic fee
the air meter in order to fill the holder, consequently the reg
more. On the other hand, when the room was colder than the
holder, the air drawn into the holder was warmed and occupied
so that less than 9 cubic feet had to pass through the air m
to fill the gas-holder, consequently the registration was less.*

The same explanation also applied to the "Blow out"
the only difference being that in these the change of temper
air which affected the registration could only take place w
passed through the pipe between the holder and the air meter
the "Draw in" experiments the change could take place after
passed through the pipe and was resting in the holder in conta
water. Consequently the air in the "Blow out" experimen
opportunity of changing temperature than in the "Draw in" e
and therefore did not change so much, and the effect on the
was not so great. The different period of time available for a
in the temperature explains why the effect produced on the r
greater in the slow than in the quick speed of the holder. In
"Draw in" experiments, when the speed of the holder was sl
seconds to rise), the difference in registration, due to the room
warmer than the water in the holder, was about 3 per cent., and
speed of the holder was considerably more (four times as muc
rise of holder in 30 seconds, the difference of registration was
1½ per cent.

In the actual experiments from which the corrections for th
air meters were obtained, the difference of temperature never
3½ degrees, and was generally considerably less. The difference
tration, due to 3½ degrees, was only ½ per cent., and this was a
in the reductions.

* The theoretical correction corresponding to a change of 10 per cent. i
perature between the meter and the gasholder, would be about 2 per cent.—[W

In the case of "Blow out" experiments when the speed of the holder was slowest (120 seconds to sink), the difference in registration, due to the room being 15 degrees warmer than the water, was less than two per cent. or two-thirds of that in the case of the "Draw in" experiments.

When the speed was faster, viz., a discharge of the holder in 60 seconds, the difference of registration was 1½ per cent., or half that in the case of the "Draw in" experiments. In the actual "Blow out" experiments the difference of temperature was never more than 4½ degrees, and generally much less. The difference in registration due to 4½ degrees is ½ per cent.

The results of the special series of experiments made on 6th and 7th June, 1884, with air meter No. 446 were plotted on a curve, from which was prepared Table IV., showing the multiplier with which to correct the register for differences of temperature of room and water.

Table IV.—Draw In Experiments at Cannon Row in 1884.

2·7-in. METER No. 446.

Table of Corrections for Differences between the Temperatures of Room and Gas Holder.

9 Cubic Feet of Air drawn into Gas-holder in 60 Seconds.
From Curve of Experiments on 6th & 7th June, 1884.

Room differs from Water.	Register as per Curve.	Ratio of Registers.	Multiplier to correct Register for Difference of Temperature in Col. 1.	Room differs from Water.	Register as per Curve.	Ratio of Registers.	Multiplier to correct Register for Difference of Temperature in Col. 1.
— 10°	287·00	·985	1·015	+ 1°	291·70	1·002	·998
— 9°	287·35	·986	1·014	+ 2°	292·20	1·003	·997
— 8°	287·75	·988	1·012	+ 3°	292·70	1·005	·995
— 7°	288·10	·989	1·011	+ 4°	293·25	1·007	·993
— 6°	288·50	·990	1·010	+ 5°	293·80	1·009	·991
— 5°	288·95	·992	1·008	+ 6°	294·40	1·011	·989
— 4°	289·35	·993	1·007	+ 7°	295·00	1·013	·987
— 3°	289·80	·995	1·005	+ 8°	295·70	1·015	·985
— 2°	290·25	·997	1·003	+ 9°	296·35	1·017	·983
— 1°	290·85	·999	1·001	+ 10°	297·10	1·020	·980
0	291·20	1·000	1·000				

The results of the "Draw in" experiments at Cannon Row, upwards of 500 in number, were entered in Table V., p. 248.

Table V.—Experiments on 2·7 Inch Air Meters. [*Revised 1st March, 1894.*

Reduction of Draw In Experiments at Cannon Row, June, 1884, with corrections applied for slight difference of temperature of Room & Water.

NOTE.—Diameter of inside of Ring of Air Meter 2·70 in.; area of Ring 5·72 sq. in. or ·03976 sq. ft., hence 1 cub. ft. passing thro' Air Meter is equivalent to 25·15† lin. ft.; 9 cub. ft. = 226·35 lin. ft. See also Diagram 5, p. 235.

Table used in plotting Standard Curves for converting Register into Actual Velocity through ring of Air Meter.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
							Temperature.				Register corrected for temperature.		
No. of air meter.	Page in Experiment Sheets	No. of Experiments.	Cubic Feet drawn in.	Time in seconds.	Cubic feet per minute.	Actual velocity in feet per min. thro' ring of air meter. Col. 6 × 25·2.	Room.	Water.	Room differs from water.	Register as observed. Feet.	Multiplier to correct Register for difference of temperature in Col. 10.	Register. Feet.	Register per minute. Feet.
611 14 June (Summary Table I.)	1	1	1	47·0	1·27	32·0	64·0°	64·0	......	0			
	1	10	2	60·0	2·00	50·4	63·7	64·0	− ·3	35·7	1·000	35·7	35·7
	1	10	3	60·2	2·99	75·3	65·2	68·0	−2·8	82·7	1·005	83·1	82·8
	2	20	9	120·4	4·48	112·9	65·7	64·0	+1·7	280·8	·997	279·9	139·5
	3	20	9	59·9	9·02	227·3	64·5	64·0	+ ·5	300·2	·999	299·9	300·4
	4	20	9	30·2	17·88	450·6	65·2	64·0	+1·2	305·8	·998	305·2	606·3
	5	20	9	20·0	27·00	680·4	66·2	64·0	+2·2	306·7	·997	305·7	917·1
619 11 & 13 June (Sum. Table II.)	1	2	1	51·0	1·16	29·2	67·5	66·0	......	0			
	1	10	2	60·0	2·00	50·4	67·5	66·0	+1·5	42·6	·998	42·5	42·5
	2	20	9	121·0	4·16	112·4	62·0	60·5	+1·5	275·4	·998	274·8	136·2
	3	20	9	59·0	9·15	230·6	62·0	60·5	+1·5	297·8	·998	297·2	302·2
	4	20	9	30·5	17·70	446·0	62·0	60·5	+1·5	303·2	·998	302 6	595·2
620 12 & 13 June (Summary Table III.)	1	2	1	52·0	1·15	28·9	64·0	60·7	......	0			
	1	10	2	60·5	1·98	49·9	64·5	61·0	+3·5	41·7	·994	41·4	41·1
	2	20	9	120·6	4·47	112·6	62·0	59·8	+2·2	279·1	·997	278·3	138·4
	3	20	9	90·0	6·00	151·2	66·0	66·5	− ·5	282·3	1·001	282·6	188·4
	4	20	9	59·5	9·08	228·8	63·1	60·2	+2·9	297·9	·995	296·4	298·8
	5	20	9	45·0	12·00	302·4	64·2	60·7	+3·5	302·5	·994	300·7	401·0
	6	20	9	30·5	17·70	446·0	63·5	60·5	+3·0	306·0	·995	304·5	599·0
	7	20	9	20·0	27·00	680·4	66·3	66·0	+ ·3	303·5	·999	303 2	909·6
(...e IV.)	1	4	1	47 0	1·27	32·0	66·5	66·0	+ ·5	0			
	1	20	2	59·9	2·00	50·4	67·0	66·0	+1·0	36·5	·998	36·4	36·5
	2	{10} 40	3	60·0	3·00	{75·6} 75·7	65·0	67·5	−2·5	79·7	1·004	80·0	{80·0} 80·3
	2	{10}	3	60·3	2·98	{75·1}	65·0	67·2	−2·2	79·8	1·003	80·0	{79·6}

In illustration of the data from which this table is compiled one example has been selected at random, from Summary Table No. 3, which is not printed.

Register.	Average.	Holder cubic feet.	Time in Seconds.	Average Time.	Temperatures. Room.	Temperatures. Average.	Temperatures. Water.	Temperatures. Average.	Room differs from Water.
278		9	120		62		59½		
278		9	120		62		59½		
278		9	121		62		59½		
279		9	120		62		59½		
282		9	119		62		59½		
	—279·0	—9		—120·0		—62·0°		—59·5°	+ 2·5°
279		9	120		62		59½		
279		9	120		62		59½		
279		9	119		62		59½		
281		9	121½		62		59½		
280		9	120		62		59½		
	—279·6	—9		—120·1		—62·0°		—59·5°	+ 2·5°
278		9	121		62		60		
279		9	121		62		60		
278		9	120		62		60		
279		9	121		62		60		
278		9	122		62		60		
	—278·4	—9		—121·0		—62·0°		—60.0°	+ 2·0°
279		9	123		62		60		
278		9	118		62		60		
280		9	120		62		60		
281		9	120		62		60		
280		9	120		62		60		
	—279·6	—9		—120·2		—62·0°		—60·0°	+ 2·0°
	279·1	9		120·6		62·0°		59·8°	+ 2·2°

From col. 7 and col. 14 of Table V. curves for each of the 2·7 inch air meters were plotted, entitled "Standard Revised Curves, March 1st, 1894, from experiments made at Cannon Row in the same month, and under uniform conditions, on 2·7 inch Air Meters." These curves (see p. 235) were used in carrying out the reduction of the dial readings of the 2·7 inch Air Meters used for the experiments upon Open Pipes, Cowls and Terminals at the Old Deer Park.

An examination of these curves was made in July, 1899, in order to compare the corrections to the dial readings for the several instruments at different speeds, and a diagram exhibiting these differences was prepared. The corrections for Nos. 611, 619, 620, go very closely together from + 20, the difference applicable to a dial registration of 20 ft. per minute, to − 160 at a dial registration of 625 feet per minute and the curve turns slightly away from the vertical axis, or axis of correction values.

6-in. Current Meter.

Tested at King's Cross; used at Stage and Hut.

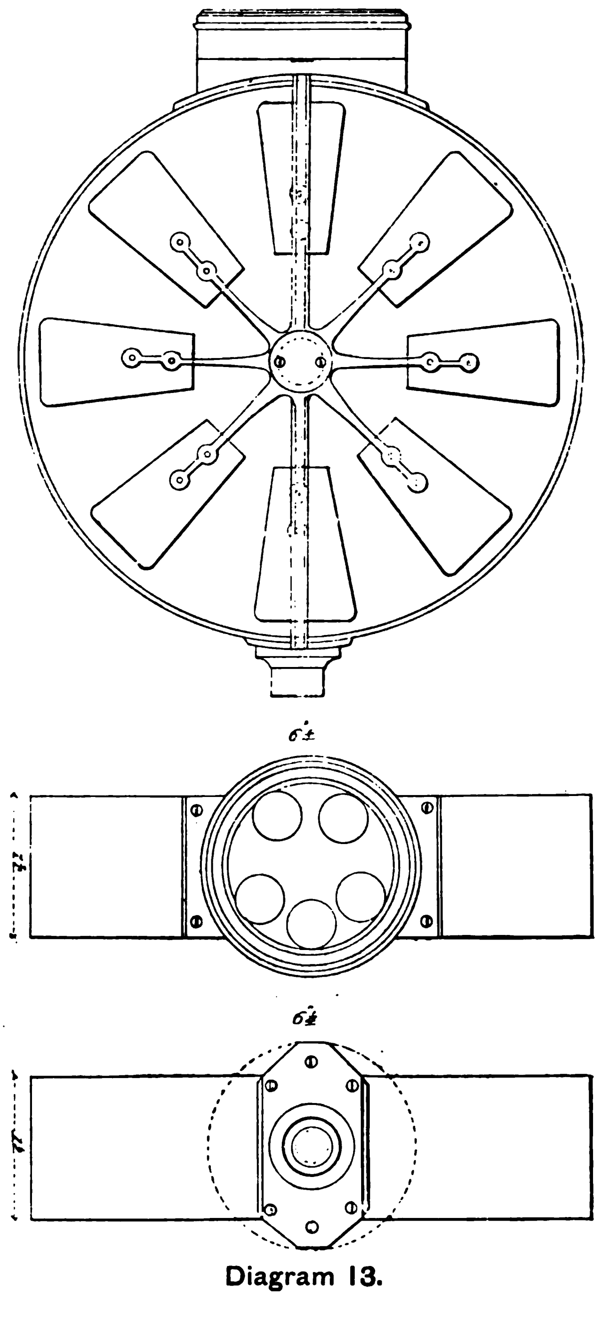


Diagram 13.

PREPARATION OF STANDARD CURVES FOR CONVERTING REGISTERED RUN INTO ACTUAL VELOCITY. 6·1-INCH AIR METERS.

The 6·1 inch air meters used for the cowl experiments were bought in October, 1879, from Mr. Lowne, anemometer maker. The Committee determined to use an improved form of air meter, and accordingly a design was prepared for an instrument as shown on Diagram 13. The chief consideration in the new design was to have a very small obstruction in the centre boss (the usual form of air meter had a large obstruction in the centre); the next point of importance was to have the supporting bars to offer the minimum resistance; and generally to make the instrument as simple as possible.

The construction of the instrument will be seen from the Diagram; there is a brass ring at the centre carrying vulcanite vanes and having a dial at the top for readings. The vanes are supported by the chamfered bars and communicate with the counting gear by a spindle running along the upper half of the bar. The small box in the centre contains the bevel wheel gearing to connect with the registering dial. The dial is made to register in feet linear, and a correction is supplied by the maker from experiments made on a whirling machine.

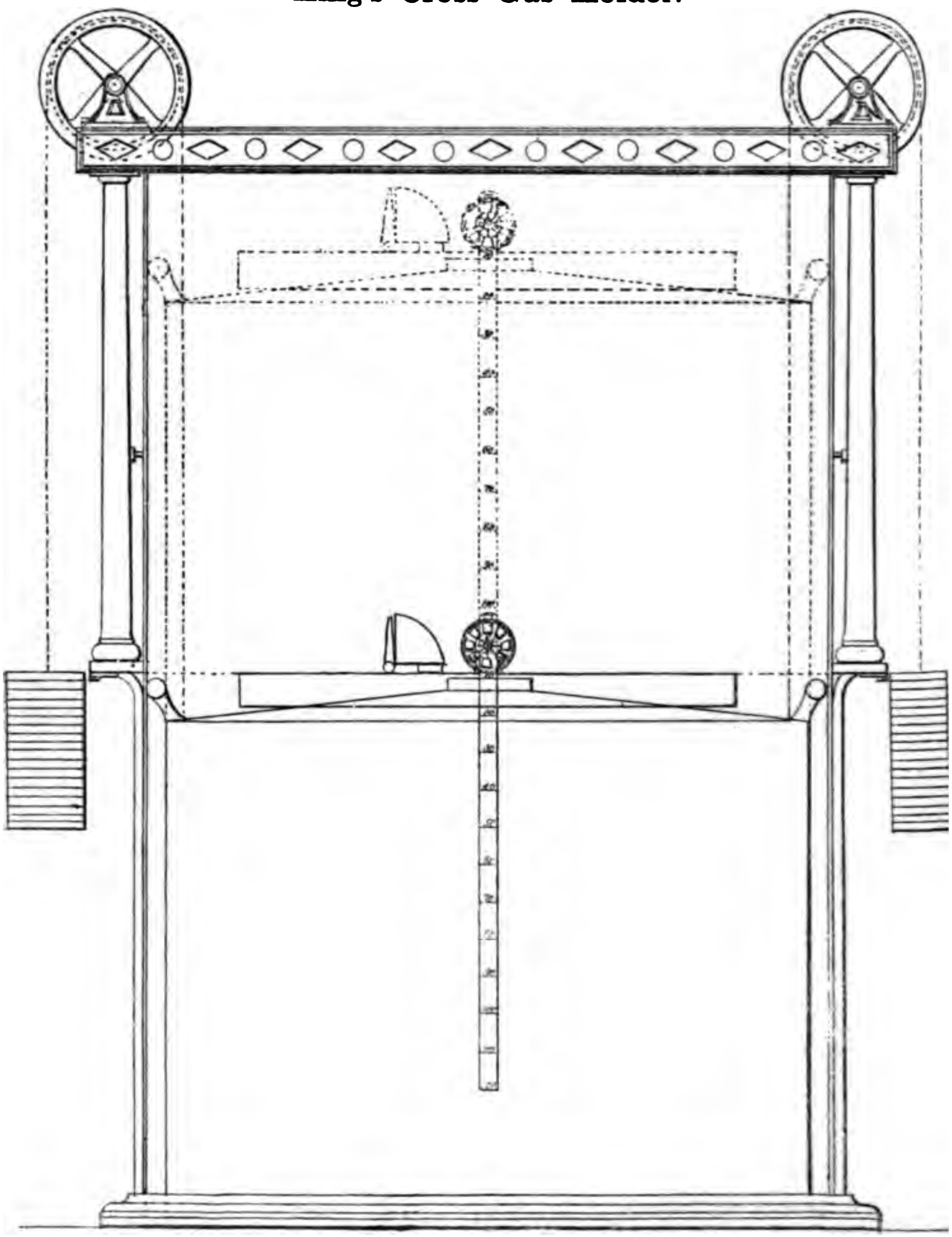
In order to plot curves for converting the register into actual velocity through the ring of the air meter three series of experiments were made, viz., experiments at King's Cross Gas Works, 1880–1881, at Cannon Row, 1884, and at the Hut in the Old Deer Park, 1886–1887, respectively.

Experiments at King's Cross Gas Works.

In order to carry out the work of testing the 6-inch meters in a similar manner to that used for the 2·7-inch air meter tests, it was found necessary to have a much larger experimental "holder" than the 10 cubic feet holder which had been used at Messrs. Sugg's Works (see p. 292), and permission was obtained through Mr. John Clark, Engineer at the King's Cross Station of the Gas Light and Coke Company, to make use of their 120 cubic feet experimental holder. Although this holder was not an ideal one for the purpose, the Committee, after making some additions to it, were able to use it.

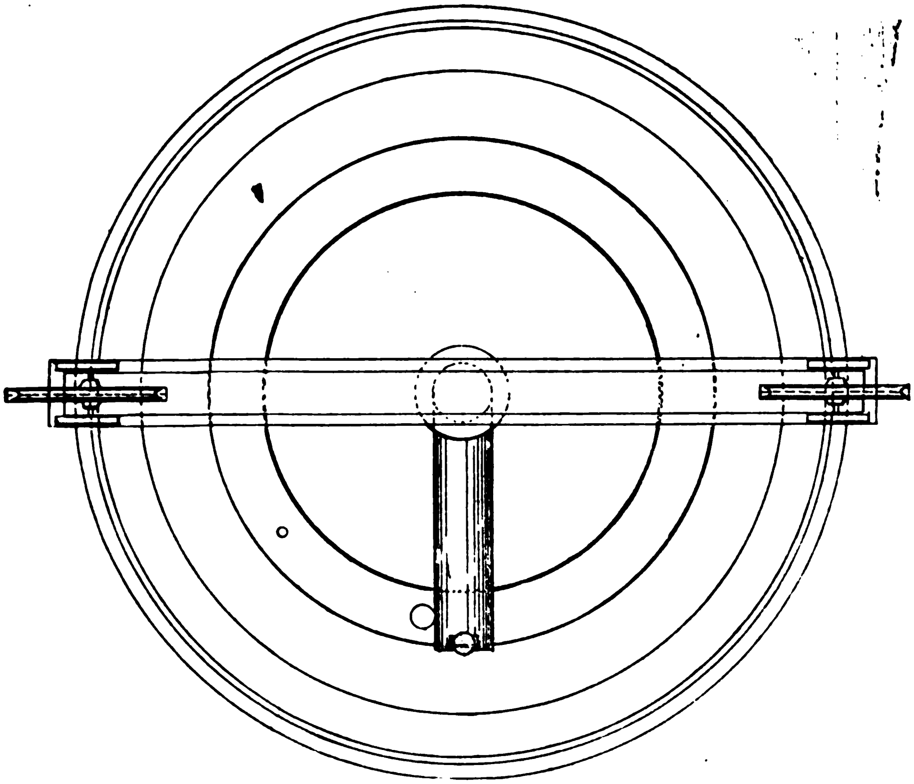
This gas holder is shown upon Diagram 14, p. 252, and consists essentially of a circular cast-iron tank 6 feet 6½ inches in diameter, having a central core of the size shown, leaving an annular space of 8 inches to be filled with water. This annular space receives the wrought-iron holder, 6 feet 1 inch in diameter, 4 feet 6 inches high, with a domed top. The holder

King's Cross Gas Holder.



ELEVATION.

Diagram 14.



PLAN.

Diagram 14.

is supported in the usual manner by cast-iron columns, a cross girder carrying grooved pulley wheels axially with the columns. Chains furnished with counter weights pass over the pulleys mentioned and are attached to the holder.

The outlet and inlet pipes, as shown in the section, are 2½ inches in diameter; however, instead of using these in the experiments, a 6-inch zinc tube of the form shown was carefully fitted at the central manhole cover, which was 6 inches in diameter. The Air Meter to be tested was fitted in the horizontal zinc tube on the top of the gas-holder. The gas-holder was provided with a scale and pointer as shown in the diagram, the scale being graduated in cubic feet and decimals of a cubic foot.

For the purpose of making accurate experiments, it was necessary that

the gas-holder should move up or down equal spaces in eq
this motion, in the case of the small holder at Messrs. Sug
effected by a cycloidal lever. For the larger holder under
the Committee adopted the suggestion to provide an annul
around the dome of the holder as shown. This trough
with water through a graduated stop-cock attached by a flex
a tank in the upper part of the room, and had a large wast
plug to empty the trough quickly, the water going direct
iron tank.

The action of this water-trough was as follows:—Wh
was raised and the weights properly adjusted for an exper
iron holder gradually entered the water-tank it lost weight,
had to be compensated for by the addition of a regular
into the annular trough. It was found after a little pra
holder could be made to run upwards or downwards through
in equal times with a fair amount of accuracy, and many
experiments were conducted in this manner for the purpose
instruments.

Two classes of experiments were conducted—first, expe
in which case the holder moved downwards; secondly, dr
the holder in this case being counterpoised to rise.

The 6·1-inch air meter to be tested was fixed at the end
tube on the gas holder, and was started and stopped by
operator with a stop-clock.

After some experience it was thought that an auto
of putting the instrument in and out of gear should be
give greater accuracy and a special apparatus was fitted
purpose and this was afterwards continuously used. F
velocities further means were employed to ensure the hold
through equal spaces in equal times, and this motion was
small crab winch attached to one of the chains of the hol
case separate readings for time and spaces travelled were
independent operator, so that great regularity was maintaine
experiments.

Upwards of 1,500 experiments* were tried with the ap
described, by drawing in (527 experiments) or blowing ou
periments) 90 cubic feet of air from the gas-holder throu

* The experiments at King's Cross were largely carried out by Mr.
assistant.

tube, on the end of which the 6·1-inch air meter was fixed. The velocity at which the air passed through the meter was calculated and compared with the velocity registered by the instrument.

The experiments were abstracted in a tabular form and were classified according to whether they were "Draw In" or "Blow out," and according to the air meter used. The abstract sheets formed six sets (viz., a "Draw In" and a "Blow Out" set for each of the three air-meters), and for convenience were called "King's Cross Gas Works Details."

By plotting various preliminary curves from these details it was found that there were great differences in the results, according to whether the air was drawn into or blown out of the gas holder. Subsequently it was ascertained that these differences could be largely reduced by fixing a tube on the side of the air meter furthest from the gas holder.

The Committee concluded that the "Blow Out" experiments at lower velocities were so irregular as to be quite unreliable. This might have been caused quite as much by the arrangement of the short curved tube leading air to the instrument as by the cross currents. The "Blow Out" experiments at high velocities were rather more regular but still not satisfactory.

The "Draw In" experiments without an added tube gave higher velocities than those with the tube, and also higher than the "Blow Out" experiments, and were considered useless for arriving at the cause of the difference.

The "Draw In" experiments with tubes 8 inch and 12 inch in length were irregular at low velocities, though rather less irregular than the "Blow Out" experiments, and the results were consequently doubtful. The "Draw In" experiments at high velocities were fairly regular, and were considered reliable.

The King's Cross Gas Works experiments therefore gave a trustworthy correction for high velocities, but not for low velocities. The Committee accordingly came to the conclusion that for low velocities results must be obtained from other experiments. To throw light upon the differences between the "Draw In" and the "Blow Out" experiments upon 6·1-inch air meters, a special comparison was made of the results of the 2·7-inch air meter experiments, viz., a comparison of "Blow Out" experiments at Sugg's Works and at Cannon Row, *without* box and gauze, with the standard "Draw In" experiments (see p. 245) at Cannon Row *with* box and gauze.

Tables were prepared embodying the following comparisons of the results for 2·7-inch meters :—

(*a*) "Blow Out" experiments carried out at Sugg 1879-80, compared with the standard "Draw In' at Cannon Row in 1884.

(*b*) "Blow Out" experiments carried out at Sugg' 1881-1882, compared with the standard "Draw ments tried at Cannon Row in 1884.

(*c*) "Blow Out" experiments at Cannon Row compa standard "Draw In" experiments at the same pl tried in 1884.

(*d*) A general summary of the whole of the preceding

To these tables an addendum was prepared in 1898, wl explanation of a revision of the figures.

The general conclusions drawn from the tables referred

(1) That the registration of the air meters in the case of ' experiments was always in round numbers from 2 to 4 per cer the standard registration of "Draw In" experiments with bo

(2) That there was no evidence that the amount of th difference between the registration of the "Blow Out" and "Draw In" experiments either increased or decreased with th

(3) That if rather greater weight was given to the Cannon ments than to the experiments at Messrs. Sugg's Works, tl between the registration of the "Blow Out" and that of the experiments might fairly be taken at 3 per cent. for all v

The revision explained in the addendum mentioned abov the adoption of this 3 per cent. average difference.

The experiments carried out at King's Cross Gas Works u air meters were then dealt with in the following way:- "Details" the interval in seconds and the register of the a each separate experiment were entered upon a table (called " Results") averaged in blocks, generally of about 19 exper classified according to whether they were "Blow Out" or experiments.

From the average of the groups of results for each air n VI., VII., & VIII., were formed, from which the Standard (plotted. In these tables the "Register per minute" of the ai the "Actual velocity per minute" for 90 cubic feet of air blown out of the holder were calculated. In these tables the average difference alluded to above was deducted from the " experiments. The results are denoted by ⊙ on the Diagram,]

Diagram 15.

GENERAL VIEW OF EXPERIMENTAL HUT AT KEW,
WITH THE COWLS AND TERMINALS TESTED.

Diagram 16.

EXPERIMENTAL HUT AT KEW.
SOME OF THE BOARDS ARE REMOVED TO SHOW INTERIOR.

Table VI.—King's Cross Gas Works, 1880—1881.

Averages from "Summary of Results" prepared in 1894.

METER No. 671.

Amount of air Drawn in and Blown out of holder=90 cubic ft.=444 lineal ft. through inside of ring of air meter, 6·1-in. diameter. Tube 6·15-in. diameter on each side of air meter.

DRAW IN.						BLOW OUT.					
Number of Experiments averaged.	Seconds for 90 cubic feet.	Register.	Register per minute.	Actual Velocity feet per minute.		Number of Experiments averaged.	Seconds for 90 cubic feet.	Register		Register per minute.	Actual Velocity per minute.
								Observed.	Corrected, see note.*		
1	2	3	4	5	6	7	8	9	10	11	12
			Plotted on Curve (p. 236) in Hollow Circles.							Plotted on Curve (p. 236) in Hollow Circles.	
19	23·8	570	1437	1119		17	20·6	600	582	1695	1293
18	23·0	575	1500	1158		17	22·7	592	574	1517	1174
15	36·0	580	967	740		17	23·0	585	567	1479	1158
18	144·8	605	251	184		17	24·2	591	573	1421	1101
18	147·7	581	236	180		17	29·7	579	562	1135	897
17	300·0	476	95	89		18	32·2	567	550	1025	827
						18	36·3	576	559	921	734
						19	47·3	581	564	715	563
						18	63·2	568	551	523	422
						19	79·8	565	548	412	334
						17	93·8	572	555	355	284
						18	102·9	572	555	324	259
						17	117·9	567	550	240	226
						19	147·3	581	564	230	181

Table VII.—METER No. 673.

1	2	3	4	5	6	7	8	9	10	11	12
			Plotted on Curve (p. 236) in Hollow Circles.							Plotted on Curve (p. 236) in Hollow Circles.	
18	23·6	569	1447	1129		18	20·5	591	573	1677	1800
18	23·3	583	1501	1143		18	22·7	581	564	1491	1174
18	23·1	569	1478	1153		19	23·3	595	577	1487	1143
18	23·4	569	1478	1138		17	23·0	601	583	1521	1158
18	23·0	569	1478	1158		18	23·0	585	567	1479	1158
19	25·0	570	1368	1066		20	23·1	584	566	1470	1153
21	35·6	573	966	748		21	23·0	587	569	1484	1158
22	38·4	574	897	694		18	28·4	586	568	1200	938
20	82·4	569	414	323		17	34·1	565	548	964	781
18	129·6	595	275	206		17	36·4	585	567	935	732
18	143·6	612	256	186		19	34·9	577	560	963	763
18	147·5	600	244	180		18	34·9	577	560	963	763
18	150·1	590	236	177		20	41·4	582	565	819	643
15	300·5	537	107	89		19	41·4	587	569	825	643
						19	46·3	583	566	733	575
						19	54·2	569	552	611	492
						20	65·4	574	557	511	407
						18	86·3	575	558	388	309
						21	104·1	572	555	320	256
						20	119·3	575	558	281	223
						21	146·1	590	572	235	182

* NOTE.—This correction is made by deducting three per cent. from column 9, as the experiments on 3-inch air meters show that the Blow Out register is on an average three per cent. more than the standard Draw In register (see comparison of Blow Out experiments with Draw In experiments).

Table VIII.—King's Cross Gas Works, 1880—1881.

Averages from "Summary of Results," prepared in 1894.

METER No. 674.

Amount of air Drawn in or Blown Out of holder = 90 cubic feet = 444 lineal feet through inside of ring of air meter 6·1 inch diameter. Tube 6·15 inch on each side of air meter.

DRAW IN.						BLOW OUT.					
Number of experiments averaged.	Seconds for 90 cubic feet.	Register.	Register per minute.	Actual velocity, feet per minute.		Number of experiments averaged.	Seconds for 90 cubic feet.	Register. Observed.	Register. Corrected see note.*	Register per minute.	Actual velocity, feet per minute.
1	2	3	4	5	6	7	8	9	10	11	12
			Plotted on Curve (p. 236) in Hollow Circles.							Plotted on Curve (p. 236) in Hollow Circles.	
20	23·2	566	1464	1148		19	21·1	597	579	1646	1263
20	31·6	563	1069	843		20	23·2	607	589	1523	1148
21	38·0	569	898	701		20	23·0	584	566	1477	1158
21	136·9	576	252	195		20	23·7	576	559	1415	1124
21	143·7	566	236	185		17	26·0	594	576	1329	1025
21	146·1	554	228	182		17	31·3	570	553	1060	851
21	148·0	546	221	180		17	36·2	561	544	902	736
18	299·9	355	71	89		18	37·1	574	557	901	718
						18	36·4	569	552	910	732
						19	41·3	577	560	814	645
						18	40·8	579	562	826	653
						19	41·5	575	558	807	642
						20	46·6	578	561	722	572
						20	59·3	580	563	570	449
						21	76·9	567	550	429	346
						21	97·8	568	551	338	272
						21	107·5	564	547	305	248
						17	136·3	554	537	236	195
						18	149·1	546	530	213	179

* NOTE.—This correction is made by deducting three per cent. from column 9, as the experiments on 3-inch air meters show that the Blow Out register is, on an average, three per cent. more than the standard Draw In register (see comparison of Blow Out experiments with Draw In experiments).

In June, 1884 (when so many experiments were tried at Cannon Row on the 2·7 inch air meters), a few experiments were also tried on the 6 inch air meters, calculating the amount of air which passed through the full area of the ring of the air meter which was actually 6·1 inches in diameter. These 6·1 inch experiments at Cannon Row, viewed in the light thrown on the subject by the 2·7 inch experiments, distinctly proved that a large number of apparently unimportant matters affected the air meters, and that the apparatus at King's Cross Gas Works had not been sufficiently accurate to test the 6·1 inch air meters properly. It was therefore decided at that time not to use the 6·1 inch air meters for

the cowl experiments, but only the 2·7-inch air meters, but this decision was subsequently changed.

Experiments at Cannon Row.

As the experiments on 2·7-inch Air Meters at Cannon Row upon the readings of thermometers and the effect of the differences of temperature of room and water in the holder on the registration of the air meters had shown that the registration was to a certain extent affected, special temperature experiments were carried out upon the 6·1-inch Air Meters at Cannon Row. Differences of temperature were obtained by artificially heating the room and cooling the water in the holder and *vice versâ*, similarly to the method adopted when carrying out the 2·7-inch experiments. To attach the 6·1-inch Air Meter to the outlet of the holder a zinc coning-piece 3 feet 10 inches in length was used, the smaller end being 2¼ inches in diameter, and the larger end 6 inches. On to the larger end the air meter was fixed. The same box and gauze was used to keep draughts from the meter, as in the case of the 2·7 inch experiments (see sketch p. 235.) Inside the box a piece of zinc tube 6 inches in diameter and 7 inches long was fixed to the ring of the air meter.

The results of the experiments were entered upon the Cannon Row Summary Table, No. IX., p. 260, averaged in blocks usually of 20 experiments, and entered upon page 6 of the tables from which the Standard Curves were plotted. These results are described by solid circles in the plotted Diagram 5, p. 235.

Experiments at Old Deer Park, Richmond.

In August, 1880, a timber stage was erected in the Old Deer Park, Richmond, and in the following month the bottom portion of the stage was boarded in so as to form a hut. A position in an open part of the Park was selected so that the wind currents should not be affected by buildings or trees. The stage was intended to be set out with its axis at right angles to the prevailing wind so that when cowls or tubes were fixed they would have the greatest exposure to the wind and work could thereby be carried on more frequently and under better conditions. At that time Mr. Baker, chief assistant at the Kew Observatory, said that the position of the new stage and hut was as nearly as possible across the most frequent winds, and that the least frequent winds were from the S.E., and the most frequent at Kew from the S.W. and N.W. Subsequently, however, two important points were discovered; firstly, that when setting out the stage sufficient attention was not paid to the question of the least

Table IX.—6·1 in. Air Meters. [*Revised to 1st March, 1894.*

Reduction of Draw In experiments, Cannon Row, June, 1884,

with correction applied for slight difference of temperature of room and water.

Tube 6·0 in. diameter on each side of air meter, and box with gauze.

NOTE.—Diameter of inside of ring of air meter 6·10 in., area of ring 29·22 sq. in., or ·203 sq. ft.: hence 1 cubic ft. passing through air meter is equivalent to 4·93 lineal ft. through inside of ring of air meter, 6·1 in. diameter.

Columns 7 and 14 were used in plotting revised curve, 1st March, 1894, solid circles.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
							Temperature.				Register corrected for temperature.		
No. of Air meter.	Page in experiment sheets.	Number of experiments.	Cubic feet drawn in.	Time in seconds.	Cubic feet per minute.	Actual velocity in feet per minute through ring of air meter, Col. 6 × 4·93.	Room.	Water.	Room differs from water.	Register as observed.	Multiplier obtained from curve to correct register for difference of temperature	Register.	Register per minute.
						Plotted on Curve in Solid Circles.	°	°					Plotted on Curve in Solid Circles.
671	Summary Table X. 1	6	9	49·0	11·0	54·2	62·5	60·0	+2·5	0		0	0
	1	20	9	44·5	12·1	59·6	62·0	60·0	+2·0	27·4	·996	27·3	36·8
	2	20	9	30·2	17·9	88·2	62·5	60·0	+2·5	49·9	·996	49·7	98·7
	3	20	9	20·0	27·0	133·1	62·5	60·0	+2·5	52·0	·996	51·8	155·4
	4	20	9	17·5	30·9	152·3	62·5	60·0	+2·5	52·8	·996	52·6	180·3
	5	20	9	14·0	38·6	190·3	62·5	60·0	+2·5	53·7	·996	53·5	229·3
673	Summary Table XI. 1	8	9	60·0	9·0	44·3	62·0	60·5	+1·5	0		0	0
	1	20	9	45·0	12·0	59·1	61·5	60·5	+1·0	24·9	·998	24·8	33·1
	2	20	9	30·0	18·0	88·7	62·0	60·5	+1·5	45·0	·997	44·9	89·8
	2	10	9	30·0	18·0	88·7	61·0	60·0	+1·0	54·5	·998	54·4	108·8 *
	3	20	9	20·0	27·0	133·1	62·0	60·5	+1·5	51·4	·997	51·2	153·6
	4	20	9	18·0	30·0	147·9	62·0	60·5	+1·5	51·9	·997	51·7	172·3
	5	20	9	14·0	38·6	190·3	62·0	60·0	+1·0	53·4	·998	53·3	228·4
	6	20	9	14·0	38·6	190·3	59·0	60·0	−1·0	54·5	1·001	54·6	234·0 *
674	Summary Table XII. 1	5	9	47·5	11·4	56·2	61·5	60·5	+1·0	0		0	0
	1	20	9	45·0	12·0	59·1	59·2	60·0	−0·8	27·5	1·001	27·5	36·7
	2	20	9	30·0	18·0	88·7	62·5	62·0	+0·5	41·6	·999	41·6	83·2
	3	20	9	20·0	27·0	133·1	62·5	62·0	+0·5	50·3	·999	50·2	150·6
	4	20	9	17·4	31·0	152·8	61·5	60·5	+1·0	50·8	·998	50·7	174·8
	5	20	9	14·1	38·3	188·8	62·5	62·0	+0·5	52·3	·999	52·2	222·1
	6	20	9	10·0	54·0	266·2	61·2	60·2	+1·0	52·6	·998	52·5	315·0

* Box and gauze taken off in these sets of experiments.

frequent winds (S.E.), as the line of the stage should have been as nearly in the line of the least frequent winds as was consistent with its being across the line of the most frequent winds,—the stage ought therefore to have been more than 9 degrees to the west of north; secondly, that the line of pipes was skewed so that their line was actually to the east of north, instead of the west of north.

A reproduction of photographs and plans of the hut in Old Deer Park is given on Diagrams 15 and 16, facing page 256; 17, 18, and 19, pages 261—263.

General Scale of Feet.

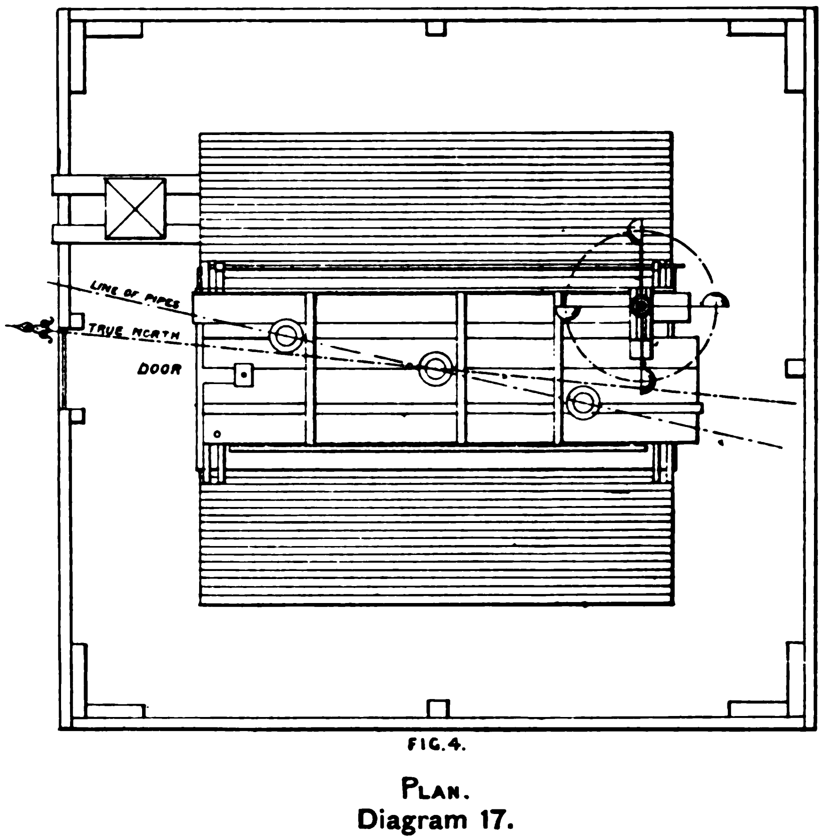
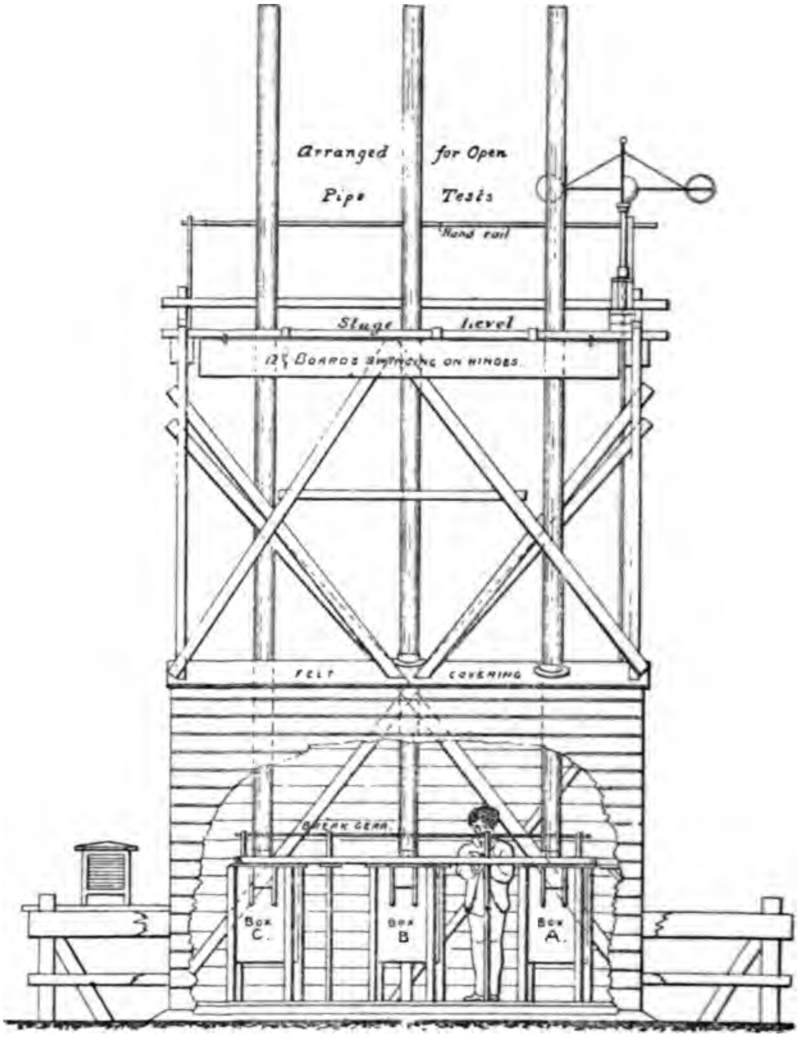


FIG. 4.

PLAN.
Diagram 17.

The ordinary apparatus used for testing was as follows: three 3 inch galvanized iron tubes 14 feet long were fixed vertically to a suitable bench

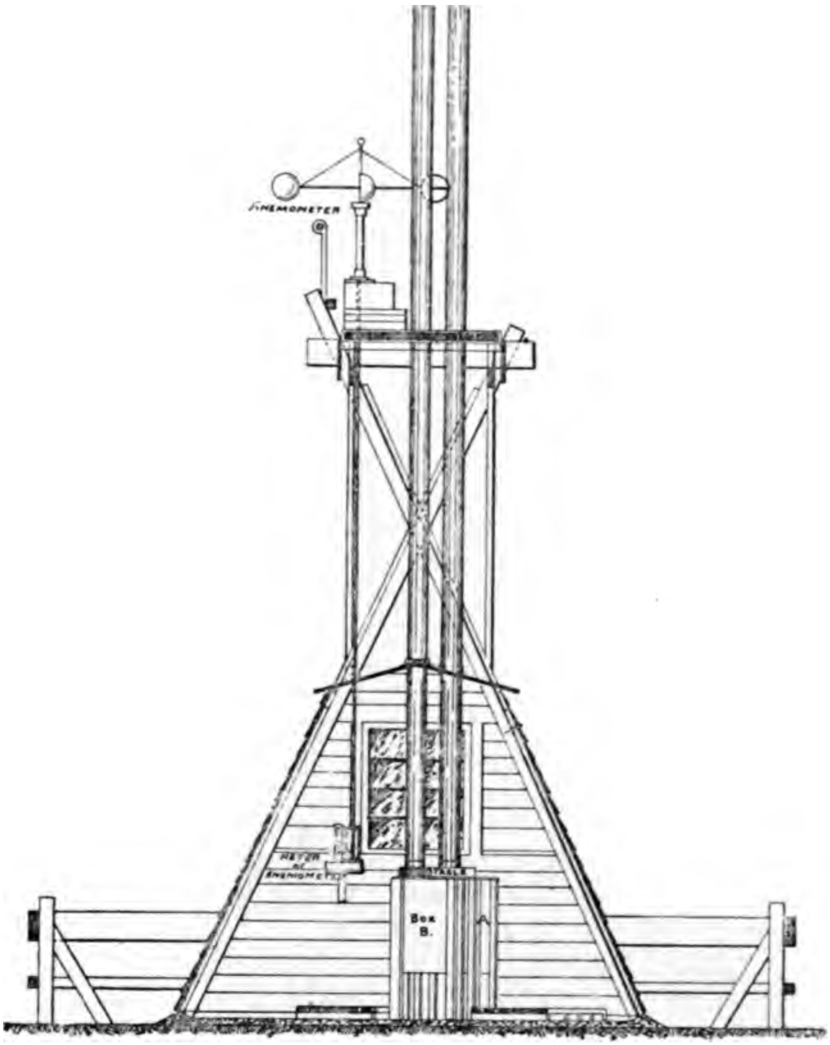


ELEVATION

Diagram 18.—Experiment Hut, Kew.

inside the hut and to the platform, and carried up from the platform, terminating 8 feet 3 inches above it. Concentric with these tubes, and

beneath them, were placed the three 2·7 inch Air Meter, on each side of which was fixed a piece of brass tube 6 inches in length. The upper



CROSS SECTION AT CENTRE PIPE.

Diagram 19.

brass tube was joined to the lower end of the long galvanized iron tube by means of a strong india-rubber band which insured a perfectly airtight

junction. Below the bench at the foot of each tube a 1′ 3½ or air chamber 1′ 8″ deep was fitted, with proper apert insertion of the air meters at the top. The bottom of each was covered with fine silk gauze so as to admit air equably cross draughts to the instruments and tubes, in accordan methods found necessary from the experiments on curren Messrs. Sugg's works in 1881–1882. The break gear, to st the instruments simultaneously, consisted of a sliding rod fitt bench with attachments to each of the air meters. A littl the east of the south tube a Robinson's Cup Anemometer, centre to centre of cups, was set up outside the hut, the revol transmitted to the recording dial by means of a long thin passed to the inside of the hut close to the bench, thus admi operator starting and stopping the three air meters, and the Cup Anemometer at the same instant. The duration of each was noted with precision by a watch, and the wind directi by an assistant who made use of a small vane close to the was taken to ascertain the temperature inside and outside the experiments were proceeding, particularly in the earlier v method adopted was the following: the operator took the rea thermometers before commencing an experiment, then star meters and anemometer; at the conclusion of the experime the readings of the instruments, then read the thermometers i then those on the platform, and immediately afterwards start experiment. The object in taking temperatures immediately immediately after an experiment was to ascertain the di temperature that took place during the experiment, for vi thermometer readings after one experiment are those i preceding the next. As a general rule the door and window were shut when upcast and injector experiments were being open during down-draught experiments.

The special experiments at the Old Deer Park, which we the preparation of the standard curves, consisted of a compari 6·1-inch air meters with the 2·7-inch air meters, for which the a corrections had been satisfactorily determined.

For this purpose several experiments were made with ea 6·1-inch air meters, by running them against 2·7-inch Air Met superposed (as shown in diagram 7, p. 237). The 6·1-inch air me 6 inch zinc tube on each side of it, was fixed in the usual the bench. On the top of this was placed a coning-piece 3 fe

high and narrowing down, including an ⅛-inch shoulder to a 2·7-inch circular orifice, into which was inserted the brass tube attached to the lower side of the 2·7-inch Air Meter. The similar brass tube on the upper side communicated (by means of a diverging tube 7½ inches high, 2·7-inches at bottom, and 6 inches at top) with the 6-inch zinc pipe, which passed through the roof of the hut to the outer air. In order to obtain a fair comparative average register in feet per minute from the 2·7-inch and 6·1-inch Air Meters, a duration of half-an-hour was allowed for each experiment. During each experiment the Anemometer recorded the wind velocity.

The results of the special experiments at the Old Deer Park were entered upon the tables from which the Standard curves were plotted, and are given in Tables X., XI., & XII.

The results of these experiments are shown on the diagram (p. 236) by crosses.

From these averaged results curves for each air meter were plotted, entitled "Standard Revised Curves, March 1st, 1894, from various sets of experiments made at King's Cross Gas Works, Cannon Row, and Old Deer Park, in different years and under various conditions, on 6·1-in. Air Meters." On these curves the base was "Register feet per minute," and the vertical "Actual Velocity per minute through inside of ring of air meter 6·1-inches diameter." The curves are reproduced on p. 236.

These standard revised curves were used in carrying out the reduction of the dial readings of the 6·1-inch air meters used for the experiments upon Open Pipes, Cowls, and Terminals at the Old Deer Park, in the same manner as that in which the 2·7-inch standard revised curve was made use of for reducing the 3-inch Open Pipe, Cowl, and Terminal experiments.

The curves thus prepared give the results of experimental comparison of the air-meter readings and gas-holder readings up to 1,000 feet per minute on the air meter. In the examination of cowls, readings on the air meter exceeding 1,000 per minute have been reduced by assuming that the line representing the relation between reading and flow may be continued as a straight line, in accordance with the indication given by the readings between 300 and 1,000 on Diagram 5, p. 235. The tendency shown by the Anemometer curves to become rectilinear at the higher velocities is borne out by the experiments at Kew by Dr. Chree, p. 229.

THE USE OF AIR METERS IN THE INVERTED POSITION.

In some of the experiments upon injectors at the experimental Hut in the Old Deer Park the air was allowed to pass down the central 3-in. pipe

Table X.—6·1-in. Air Meter No. 671.

Results obtained by comparing with 2·7-in. Air Meters at Old
October, 1886, to February, 1887.

Tube 6·0 in. diameter on each side of Air Meter.

2·7 in. METER No. 611.				6·1 in. METER No. 67			
Robinson's Cup Anemometer.	Register. In 30 minutes.	Register. Per minute.	Velocity per minute thro' 2·7″ meter, corrected from curve.	Register. In 30 minutes	Register. Per minute.	Velocity per minute thro' 6·1″ meter, calculated from 2·7″ meter = Col. 4 ÷ 5·11.	Index Nos.
1	2	3	4	5	6	7	8
Revolutions.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	
					Plotted on Curve in Crosses.		
1764	37,871	1262	937	6853	228	183	624
1619	35,550	1185	880	6373	212	172	621
1553	32,807	1093	812	5904	197	159	622
1384	31,908	1063	789	5725	191	154	623
1076	28,757	958	711	5142	171	139	642
636	24,960	832	618 } 608	4467	149 } 146	121 } 119	647
670	24,520	817	607	4342	145	119	646
1013	24,483	816	606	4372	146	119	637
848	24,319	810	601	4330	144	118	635
807	20,762	692	514	3649	122	100	636
732	19,451	648	482	3274	109	94	628

NOTE.—The following experiments

Table XI.—6·1-in. Air Meter No. 673.

2·7 in. METER, No. 611.				6·1 in. METER, No.		
Robinson's Cup Anemometer.	Register. In 30 minutes.	Register. Per minute.	Velocity per minute through 2·7 in. meter, corrected from curve.	Register. In 30 minutes.	Register. Per minute.	Velocit per minu throug 6·1 in. me calculat from 2·7 meter, Col. 4 ÷ 5
1	2	3	4	5	6	7
Revolutions.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
					Plotted on Curve Crosses.	
1127	28,078	936	694	4902	163	136
1004	26,973	899	667	4666	156	131
1065	26,072	869	645	4405	147 } 146	126 } 12
1015	26,093	869	645	4375	146	126
972	24,288	809	601	4141	138	118
481	21,679	722	536	3755	125	105
461	18,307	610	453	3094	103	89
	14,540	484	361	2235	75	71
	14,174	472	352	2017	67	69
	13,576	452	337	1788	60	66
	11,373	379	284	1202	40	56

NOTE.—Ratio of areas: $\frac{\text{6·1 in. meter, 29·22 sq. ins.}}{\text{2·7 in. meter, 5·72}} = 5·11.$

Table XII.—6·1-in. Air Meter No. 674.

Results obtained by comparing with 2·7-in. Air Meters at Old Deer Park, October, 1886, to February, 1887.

Tube 6·0 in. diameter on each side of Air Meter.

2·7 in. METER, No. 611.				6·1 in. METER, No. 674.			
Robinson's Cup Anemometer.	Register. In 30 minutes.	Register. Per minute.	Velocity per minute through 2·7 in. meter, corrected from curve.	Register. In 30 minutes.	Register. Per minute.	Velocity per minute through 6·1 in. meter, calculated from 2·7 in. meter, = Col. 4 + 5·11.	Index Numbers.
1	2	3	4	5	6	7	8
Revolutions.	Feet.	Feet.	Feet	Feet.	Feet.	Feet.	
					Plotted on Curve in Crosses.		
1352	33,577	1119	831	5683	189	163	633
1010	26,042	868	644 } 640	4091	136 } 139	126 } 125	634
991	25,750	858	637 }	4251	142 }	125 }	629
975	23,647	788	585	3716	124	114	641
748	21,472	716	532	3205	107	104	640
332	16,868	562	418	1939	65	82	650

NOTE.—Ratio of areas: $\frac{\text{6·1 in. meter, 29·22}}{\text{2·7 in. meter, 5·72}} = 5·11.$

and passed the air meter placed in position for measuring the upcast flow. The air accordingly struck the back of the vanes and the pointer ran backwards over the dial. A special series of experiments was instituted to ascertain what correction if any ought to be applied to the readings of the meter on account of this reversal of the usual direction of flow with reference to the meter. The experiments were carried out partly at Messrs. Sugg's Works, partly at Cannon Row, and partly at the experimental Hut. In the two first mentioned, air from a gas holder was driven past the air meter in the direct and reversed direction alternately. Slight modifications were made in different experiments by varying the length of the tube which continued the flow of air beyond the meter, and also by covering more or less of the projecting tube with a box. In the experiments at Old Deer Park the air meter was placed in the direct and reversed position successively at the foot of the central pipe, and the downcast or injection reading of the meter was compared with the simultaneous mean upcast reading of the two outside pipes, the central pipe being surmounted by an injector cowl. These comparison numbers having been obtained, a ratio for the air meter reversed to that for the air meter direct was then taken to represent the comparative effect of the reversal.

The results obtained from 180 experiments were as follows:

Place of Experiment.	No. of Meter.	Number of Experiments.	Ratio of Readings of I Corresponding Re Meter Reve	
			Maximum Ratio.	Minimum Ratio.
Messrs. Sugg's Works	620	6	1·23	1·20
Do. Do.	619	31	1·19	1·11
Cannon Row	446	120	1·174	1·114
Old Deer Park..	611	23	1·16	1·07

With reference to the possibility of change of result by int the meters, the following note by Mr. Rymer Jones appears:—

"The meters were occasionally oiled, and sometimes inte results seemed doubtful, but in no such trials were any differenc (Sept. 4th, 1893.)

Subsequently, on 4th December, 1895, and 30th Noven further experiments were made by changing the positions Meters, when very slight percentage differences between the re of the meter in the centre pipe and the mean of the corrected outside pipes were observed, as shown by the following results:-

	Percentage Difference from Mean.			
	Meter 446 on centre Pipe.	Meter 619 on centre Pipe.	Me'er 620 on centre Pipe.	Meter 611 on centre Pipe
	+ 1	0	0	− 4
	+ 1	0	− 1	− 1
	+ 1	+ 1	− 2	− 3
	0	0	− 1	
	0	0		
		0		
		0		
		0		
		0		
Averages......	+ 0·6	+ 0·1	− 1·0	− 2·7

Testing of the Air Meters.

It is to be noted that the Air Meters were all tested with in a vertical plane, but were used with the wheel horizontal. evidence to show whether this difference of position would readings.

PART III.—DETERMINATION OF WIND VELOCITIES.

For the purpose of obtaining readings of the actual wind velocity over the openings of the Cowls, the Committee employed various instruments; for velocities exceeding 13 miles per hour a Kew Pattern Robinson Anemometer (9-inch cups, 2-feet arms) was used; for lower velocities a similar anemometer but of the miniature scale of 1 inch for the cups and 1¾-inch arms, was employed. The Kew Pattern instrument was continuously working throughout the investigation, and nearly all the cowl experiments have a corresponding reading of the anemometer. The 1-inch cup instrument was only occasionally employed.

The highest wind recorded at the Hut occurred on 12th Jan., 1899, when the force of the wind was too great to allow of cowl measurements being carried out. Readings of the Kew Pattern anemometer were taken for each minute from 2.30 to 2.50 p.m., and show (using 3 as factor) a mean velocity of wind of 43 miles per hour, and a maximum velocity of 56 miles per hour as computed from the run of a minute.

For certain special investigation a Dines Pressure Tube Anemometer was employed, and there are sufficient simultaneous readings of all these instruments to furnish materials for a comparison with the corresponding flow in the 3-inch open pipes mounted at the Hut.

The Committee took great pains to ascertain the factors necessary for reducing the readings of the instruments. For the 1-inch cup anemometer a special experimental investigation was made for the Committee by Mr. W. H. Dines. The Kew Pattern Robinson Anemometer had been lent by the Kew Committee, and was the actual instrument upon which experiments had been made by mounting it on a merry-go-round in the open air at the Crystal Palace in 1872 and 1881. The results of this latter comparison were discussed by Prof. Stokes in a paper read before the Royal Society in May, 1881.

The determination of the proper factor for the Robinson anemometer has given rise to a great deal of discussion. Dr. Robinson partly on theoretical grounds and partly as the result of experimental investigation, had assigned the factor 3 as appropriate for converting the actual run of the cups into the distance traversed by the air passing the cups, and the

factor is still employed in adjusting the mechanism of the ins give direct readings of wind velocity, but subsequent expe searches, some of which are referred to in the foot-note on t following pages, tend to show that this factor, except for very is distinctly too high, and that for winds exceeding 10 miles factor of from 2·2 to 2·4 would give results corresponding nearly with the actual velocity of the air. The precise f adopted would really depend upon the particular instrumen and its condition as regards lubrication and other circumstance

Mr. Rogers Field made very extensive enquiries into the vestigations of the anemometer constants*, and entered into dence with Mr. S. P. Fergusson, of Blue Hill Observatory Mr. W. H. Dines of Oxshott, and in the end decided to ado of results given in Prof. Stokes' paper, taking the registered number of revolutions, and making no allowance for natural wi

It is unnecessary to enter here into any discussion as to w factors so obtained were really the most appropriate for the instrument in use. What is wished is to place before the results which, so far as can be ascertained from the materials l would have been adopted by the Cowl Committee in view of th tion at their disposal.

The results adopted are plotted on Diagram 20. They reading for rotation of the whirling machine (shown on p. 275) and against sun, and the mean of the two which was adopte reduction of the anemometer readings.

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* Note.—The following is a list of papers abstracted or consulted by M considering the Constant of the Anemometer.

"Description of an Improved Anemometer." T. R. Robinson, D.D. ......

"Bestimmung der Anemometer Constanten," by F. Dohrandt. Wild's Repertorium, T. IV., No. 5. ... ...

"Notes on the Theory of the Cup Anemometer and the determination of its constants," by the Rev. T. R. Robinson, D.D., read 13th Dec., 1875.

"Proceedings, Royal Irish Academy," 2nd Series, Vol. II.... ... ...

"Bestimmung der Anemometer Constanten—Fortzetzung," by F. Dohrandt. Wild's Repertorium für Meteorologie, T. VI., No. 5 ... ...

"On the determination of the Constants of the Cup Anemometer," by T. R. Robinson. Phil. Tr., Part II. ... ...

"On Observations on the Velocities of Winds, and on Anemometers," by G. A. Hagemann. Quarterly Journal of the Meteorological Soc, Vol. V., p. 203

Kew Pattern Robinson Cups.

Crystal Palace Experiments, 1881.

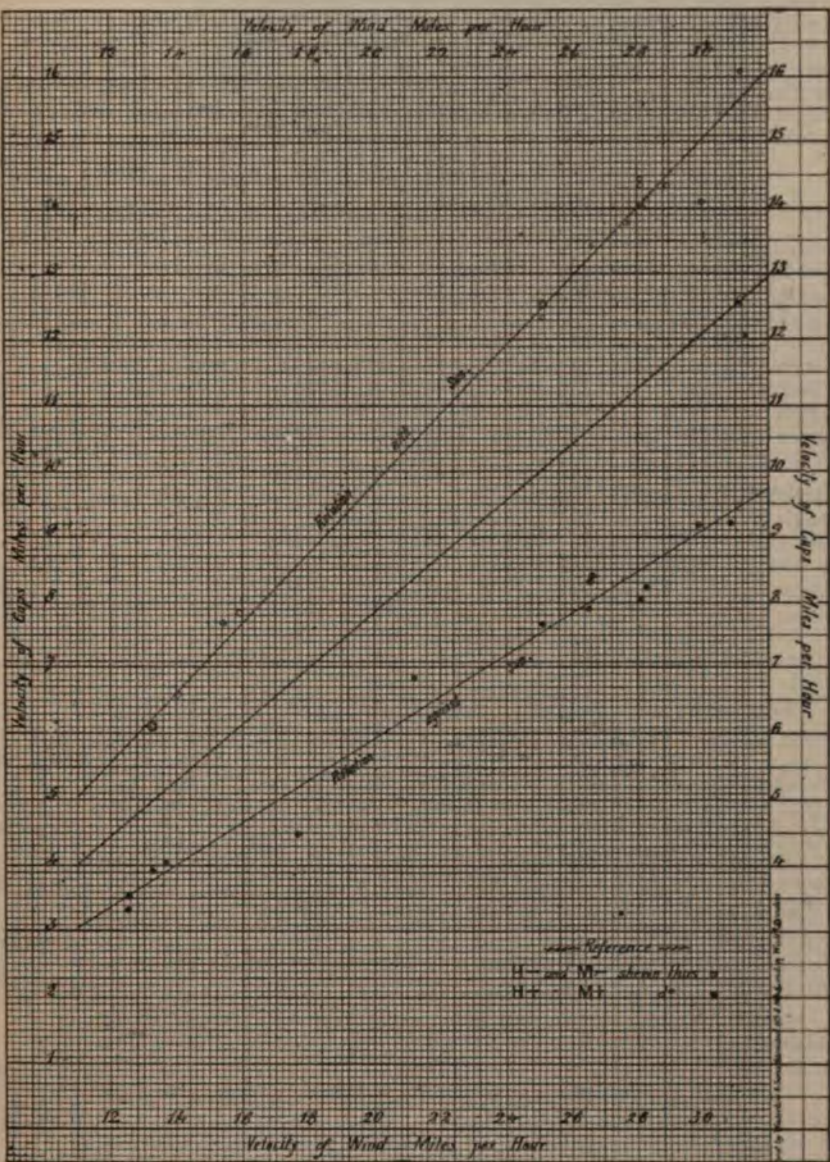


Diagram 20.

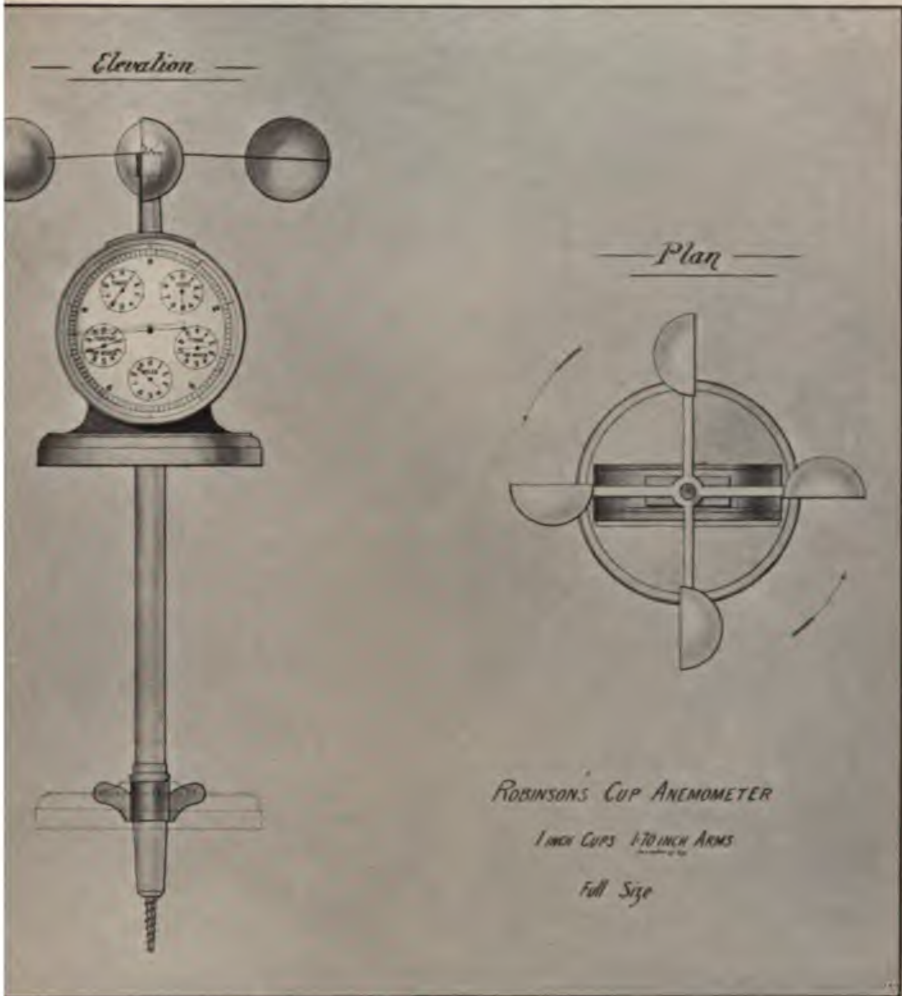
Rough List of Designers of Anemometers.

The following rough list of designers of Anemometers was also prepared by direction of the Committee, and it is reproduced here without addition or modification. It is probably based upon the catalogue of instruments exhibited at the Royal Meteorological Society. It will be noticed that Mr. Dines's name does not appear in the list, and it was probably drawn up before the well-known instrument designed by him was in use. A specimen of the instrument was, however, employed for part of the period of the Cowl Committee's experiments at the Hut in the Old Deer Park, and its indications are employed as the basis of a comparison of the various records taken at the Hut. (p. 283, Table 15, and Diagram 25, p. 286.

Name.	*Where information may be found.*
Adie's Small Recording	Maker.
Ballingall.	
Beaufoy	Ann. of Philos., N. Series, Vol. II., p. 431.
Beckley	Met. Office Reports.
Bianchi.	
Biram (Davis)	Any optician.
Bouguer...	Manœuvre des Vaisseaux, p. 151, or Traité du Navire.
Brewster	Brewster—Edinb. Ency., Article "Anemometers."
Burton	Martin—Philos. Britt., Vol. II., p. 211.
Burton (Charles) ...	(38, Barclay Road, Walham Green) Nature, Sep. 29, p. 510, Oct. 20, 1881, p. 583.
Casella's Embossing ...	Maker.
Cator's	Met. Mag., Vol. II., p. 123.
Combe.	
Crossley	Inventor.
Cronne	Phil. Trans., 1667.
Curtis.	

Notes on the measurements of Wind Velocity: Results of recent experiments, by Prof. C. F. Marvin. American Meteorological Journal, Vol. 5, p. 552	April, 1889.
Vol. 6, p. 115	July, 1889.
The measurement of Wind Velocity, by C. F. Marvin, Assistant Prof. Signal Service. Monthly Weather Review, United States Signal Service, Vol. XVII., p. 52 ...	Feb., 1889.
Comparison of Anemometers, by Asst. Prof. C. F. Marvin, U.S. Signal Service Monthly Weather Review, Vol. XVIII., p. 22 ...	Jan., 1890.
Anemometer Comparisons, by S. P. Fergusson. American Meteorological Journal, Vol. 9, p. 421 ...	Jan., 1893.
Rev. Fenwick Stow's Experiments on large and small Anemometers. Quarterly Jnl., Met. Soc., Vol. I., p. 41 ...	April, 1872.
Experiments on Anemometers and other methods of measuring the movement of air in pipes by means of a gas-holder of the Town Gas Works, Breslau. ...	1887.
Wind Pressures and Measurement of Wind Velocities, by Prof. Marvin. Am. Met. Journal ...	Feb., 1891.
"Anemometer comparisons at the Blue Hill Meteorological Observatory by S. P. Fergusson." Extracted from the annals of the Astronomical Observatory of Harvard College, Vol. XL., part IV.	

Diagram 21.



MINIATURE ROBINSON CUP ANEMOMETER.

Name.	*Where information may be found.*
Dalberg	Anémomètre proposé aux amateurs de météorologie, Enfurt, 1781, and Rozier, Vol. XVII.
De La Rue.	
Demenge	Rozier—Observations, Vol. XV.
Dechevrens.	
D'Ous-en-Bray ...	Hist. de l'Acad. des Sciences, ann. 1734, p. 123; or Mémoires, p. 169.
Dollond	Description of the Atmospheric Recorder. G. Dollond.
Eccard	History of the Signal Service, U.S.A., p. 40.
Fletcher.	
Forbes	Negretti and Zambra.
Foster	Instructions to Observers—Canada—by G. T. Kingston.
Galton—torsion.	
Gibbon	History of the Signal Service, U.S.A., p. 39.
Green	Instructions to Observers—Canada—by G. T. Kingston.
Hagemann (Patt. I.) ...	Met. Office.
" (" II.) ...	Mr. Rogers Field.
Halleur	Any optician.
Harris, Sir W. Snow ...	Met. Office.
Hennessey	Inventor—Professor H. Hennessey, F.R.S., Idrone Terrace, Blackrock, Dublin.
Hermann	Mechanisch-verbesserter Windmesser, u.s.w. Freiburg, 1789.
Hervé-Mangon	Inventor—or Bréguet, or Annuaire de Montsouris.
Hick's Electric ...	Inventor.
Howlett.	

Anlagen zum Hauptberichte der Preussischen Schlagwetter Commission. Band V., p. 123. Verlag von Ernst & Korn, Berlin	1887.
Experiments on Centrifugal Fans by Bryan Donkin. Minutes, Inst. C. E., Vol. CXXII., Part IV. Appendix III. Summary of Report by Mr. Althaus.	
Robinson's Cup Anemometers: Difference in the number of revolutions of the cups according to the direction of the revolution when tested on whirling machine. Dohrandt's Experiments...	1878.
Experiments with Whirling Machines. Report of the Wind Force Committee., Quarterly Journal, Met. Soc., Vol. XVI., p. 26	Jan., 1890.
Report of the Wind Force Committee on the Factor of the Kew Pattern Robinson Anemometer, drawn up by W. H. Dines, B.A., F.R.Met.Soc. Quarterly Journal of the Royal Meteorological Society	Jan., 1890.
Anemometer Comparisons, by W. H. Dines, B.A. Quarterly Journal of the Royal Meteorological Society	July, 1892.
Experiments by comparison with Helicoid. Report of the Wind Force Committee, Quarterly Journal, Met. Soc., Vol. XVIII., p. 165	July, 1892.
Report of the Wind Force Committee on Experiments with Anemometers conducted at Hersham, drawn up by G. M. Whipple, B.Sc., F.R.Met.Soc., and W. H. Dines, B.A., F.R.Met.Soc. Quarterly Journal of the Royal Meteorological Society	Oct., 1888.

Name.	*Where information may be found.*
Jelinek	Beiträge zur Kentness selbst registrerender Meteor-Apparate.
Kingston	? = Gibbon. *See* Instructions to Observers—Canada.
Kreil	Entwurf eines meteoro. Beobacht für dei oestereische Monarchie. Wien, 1850.
Leslie	Leslie Experimental enquiry on heat.
Leutmann	Instrumenta meteorologiæ inservientia, Wittemberg, 1725, p. 116.
Lind No. 1	Any optician (Lind No. 2—Snow Harris, *which see*).
Lomonossow	Nov. comment Petrop., 1749, t. II., p. 128.
Lowne	Maker.
Martin	Philos. Brit., Vol. II.
Morgan	Inventor.
Nollet	Art. des expériences, Vol. III., p. 62.
Oertel	Gothaiches Magazin, Th. 4, S. t. I., S. 89.
Osler	Inventor.
Ottinger...	Mr. Whipple.
Pastorelli.	
Pelisson	Beobachtungen und Entdeckungen aus der Naturkunde. Berlin, 1790, Th. 10.
Pickering	Phil. Trans., Vol. XLIII.
Polini	Polini—De la meilleure manière de mesure sur mer, &c.
Poschmann	Voigt's Magazin, Jena & Weimar, Band VII., S. 463
Prestel.	
Prigoulx	Leçons de Physique de l'École Polytechnique.
Recknagels.	
Reguier	Bulletin de la Société d'Encouragement, &c., No. 150.
Robinson.	
„ disconnecting	Negretti and Zambra.
Ronalds.	
Schmidt...	Poggendorff, Annalen, 1459.
Shaw	Inventor.
Stow.	
Theorell...	Inventor.
Valz	Zach-Correspondence astronomique, Vol. X., p. 340.
Ventosa	Nature, Nov. 24, 1881.
Wheatstone	? 12th B. A. Report.
Whewell	7th & 8th B. A. Report.
Wild.	
Wolff	C. Wolff—Elementa matheseos universae, Haloc, 1743, Vol. 2, p. 405.
Yeates	Makers.
Zeiher	Nov. comment. Petrop., t. X., p. 302.
Anonymous=Prestel ...	Phil. Trans, No. 24, *i.e.*, Vol. 1 or 2.

Tests of the Miniature (1 inch Cup) Anemometer.

This instrument was lent to the Cowl Committee by the late Mr. G. M. Whipple, Superintendent of the Kew Observatory, and in the absence of any well established factor of reduction for the instrument arrangements were made for a special investigation. The instrument is illustrated in diagram 21, facing page 272; the diagram was reproduced from a full-sized drawing, but the words "full size" which occur on the diagram are, of course, incorrect, as the drawing is considerably reduced in reproduction. The chief purpose of the instrument, from the point of view of the Cowl Committee, seems to have been to determine the velocity of air over the cowls when less than 13 miles per hour; below that limit no determinations of the factor of the Kew pattern instrument were available.

A determination of the factors of the instrument by means of a whirling machine had been made in 1889 by Mr. Dines at Hersham (see

Whirling Machine and Driving Apparatus at Oxshott, Surrey.

Fitted up May 1897. Whirler Revolving with Sun.

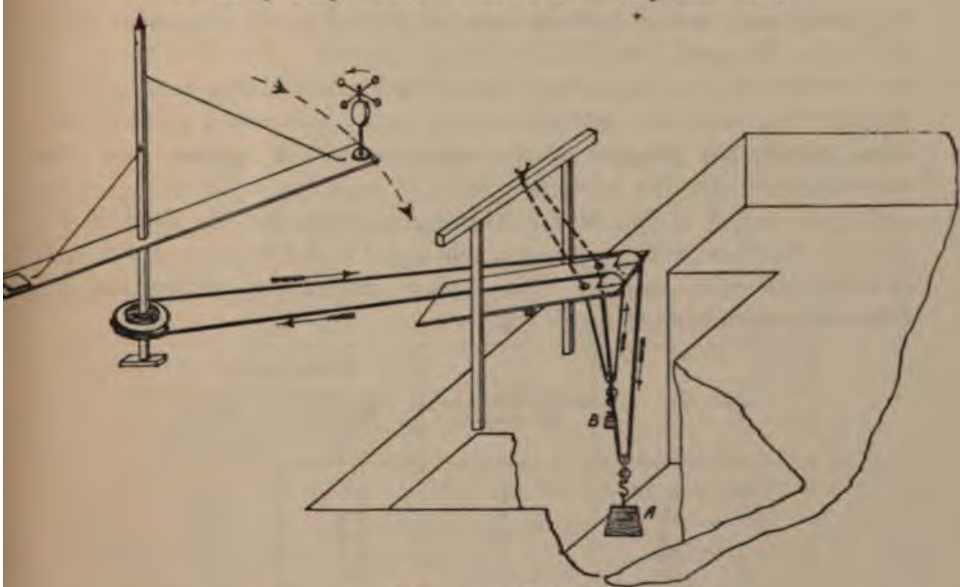


Diagram 22.

Note.—When the driving apparatus is not being wound up weight A falls and weight B rises; when being wound up the reverse action takes place, the arrangement being similar to that used in winding up astronomical clocks.

Table XIII., p. 278), and as the observations did not give extensive series of results, a further investigation was consid

Accordingly in 1897 Mr. Dines carried out a series of ex the Committee by fixing the 1 inch cups (miniature) Robinso on his whirling machine at Beverstone, Oxshott, Surrey. T carrying out the experiments is shown on diagram 22, p. 275. results are given in Table XIV., p. 279.

From notes of a lengthy correspondence with Mr. Di experiments, it appears that some uncertainty still attached t to be taken as an appropriate correction for "mitwind," th to the circulation of air which is gradually established wh apparatus is worked inside a building, as was the case with th in question. A subsidiary investigation into the effect of therefore to be made. The measurement of the amount of difficult to determine. A special apparatus was designed a Mr. Dines, consisting of a mica flap which was sensitive to ai slow as 0·1 to 0·2 mile per hour, and which indicated th mitwind created during each experiment. This was found t and not a percentage of the velocity (Mr. Dines' letter, 9th The initial tests showed that the mitwind arrived at its per well before the tenth turn of the whirling machine. The fin for mitwind was not determined from direct experimental r but also from deductions and conclusions from observations Dines during the progress of the experiments. It appea correspondence that the correction must be regarded as dep the actual length of run of the whirling machine, and the per cent. for runs of one-tenth of a mile and 4·6 to 7·0 per c of a half mile were adopted. The former number was deri following experiments of April, 1897 :—

Date, 1897.	Whirler (One-tenth mile run). Miles per hour.	Mitwind per cent.	
		Whirler Revolving with Sun.	Whirler Revolvin against Su
April 10 & 12	10	5·1	3·5
" 30	8	5·9	3·9
" 9	$6\frac{3}{4}$	5·0	3·7
" 30	6	6·3	3·9
" 30	3 to 4	3·8	3·1
" 9, 10 & 12	3 to $3\frac{1}{2}$	5·5	3·0
	Average ...	5·3	3·5
		Mean 4·4	

The latter numbers (4½ to 7 per cent.) were derived from the following experiments in December, 1896, and May and June, 1897 :—

Date.	With Sun.			Against Sun.			Average of, with Sun and against Sun per cent.
	Whirler, miles per hour.	Mitwind.		Whirler, miles per hour.	Mitwind.		
		Amount.	Per cent. of Whirler.		Amount.	Per cent. of Whirler.	
1896.							
Dec.	14	...	...	...	...	...	5·6
	7	...	...	...	...	...	8·3
	10·5						7·0
1897.							
23 May.	15	...	6·6	15	...	6·2	
25 "	15	...	6·8	15	...	6·5	
24 "	10	...	8·7	10	...	7·7	
25 "	10	...	6·0	10	...	4·6	
	12·5		7·0	12·5		6·3	6·6
23 May.	7·0	...	5·3	7·0	...	7·6	
8 June.	5·64	·34	6·0	6·32	·31	4·9	
9 "	5·37	·24	4·5	4·81	·17	3·5	
9 "	5·37	·22	4·1	4·80	·16	3·3	
	5·84		5·0	5·73		4·8	4·9
8 June.	4·20	·30	7·1	3·41	·11	3·2	
8 "	2·68	·15	5·6	3·77	·17	4·5	
9 "	2·95	·07	2·4	2·80	·16	5·7	
9 "	2·77	·08	2·0	2·66	·15	5·6	
	3·15		4·5	3·16		4·8	4·6

Preliminary experiments on 29th December, 1896, had given 7 as the mean percentage correction, with a run of ·45 miles. The corrections for mitwind based upon these observations, which represent the outcome of the investigation initiated by the Cowl Committee, are as follows :—

Miles per hour recorded ...	2½	4	6	8	11	15
Correction for mitwind, per cent.	4½	5	5½	6	6½	7

Adopting these corrections, viz., 4°/₀ for $\frac{1}{10}$ mile run, and 4½ to 7°/₀ for ½ mile run, Mr Dines's results at Oxshott for the comparison of the whirler with 1-inch cup anemometer become, as shown in table XIV., and they are plotted on Diagram 24, p. 281. The results of the Hersham experiments in 1889 are given in table XIII., and from both this table and an intermediate curve is drawn the final curve which gives the computed relation, at any speed, between the true wind velocity and the indications of the cups.

Table XIII.—Miniature Robinson Anemo
1-in. Cups, 1¾-in. Arms.

Experiments by Mr. W. H. Dines at Hersham, 18

Arm of Whirler 27 ft. Whirled against Sun $\frac{1\cdot75}{27\times12}=$

1	2	3	4	5	6	7	8
Index Number of Experiment.	Whirler. miles per hour.		Cups. miles per hour.		Factor.		Cups for motion in straight line, Col. 5, plus 1%.
	Separate Experiment.	Average.	Separate Experiment.	Average.	Separate Experiment. Col. 2. / Col. 4.	Average.	
23	3·88	3·88	1·20	1·20	3·23	3·23	1·21
76	12·80		4·68		2·74		
92	14·44		5·27		2·74		
91	16·08	14·44	5·77	5·24	2·79	2·76	5·29
85	19·20		7·21		2·66		
84	19·32		6·99		2·76		
83	20·08	19·53	7·07	7·09	2·84	2·75	7·16
88	20·92		7·57		2·76		
77	22·16		8·12		2·73		
87	22·28	21·79	8·07	7·92	2·76	2·75	8·00
86	24·80		9·27		2·68		
82	25·84		9·07		2·85		
90	26·24		9·45		2·78		
78	26·32	25·80	9·48	9·32	2·78	2·77	9·41
99	26·36		8·92		2·96		
95	27·60		10·12		2·73		
98	27·60	27·19	10·73	9·92	2·57	2·75	10·02
96	30·68		11·49		2·67		
97	31·24		11·44		2·73		
94	31·56	31·16	12·16	11·70	2·60	2·67	11·82

Col. 8 plotted on Diagram 23 (facing p. 280).

Table XIV.—Miniature Robinson Anemometer.
1-in. Cups; 1¾-in. Arms; Arm of Whirler, 7·56 feet.

Complete Table of Results of Experiments by Mr. W. H. Dines at Oxshott, Surrey, 1896–1897, with correction for Mitwind.

1 — Whirler revolving with sun.

Index Number of Experiment.	Run of Whirler, miles.	Deduct for Mitwind, per cent.	Artificial Wind, miles per hour.	Cups, miles per hour.
11	·45	4·4	2·07	·52
122	·50	4·6	2·56	·72
130	·50	4·6	2·64	·77
129	·50	4·7	2·81	·85
75	·10	4·0	2·83	·89
48	·10	4·0	2·88	·90
10	·45	4·7	2·86	·95
—	·10	4·0	3·00	·95
			2·71	·82
50	·10	4·0	3·14	1·05
56	·10	4·0	3·14	1·00
81	·10	4·0	3·14	1·03
—	·10	4·0	3·29	1·10
54	·10	4·0	3·29	1·05
52	·10	4·0	3·35	1·11
87	·10	4·0	3·75	1·25
123	·50	5·0	3·99	1·34
			3·39	1·12
83	·10	4·0	4·93	1·71
127	·50	5·4	5·08	1·76
128	·50	5·4	5·08	1·78
121	·50	5·4	5·34	1·88
8	·45	5·5	5·67	2·04
9	·45	5·5	5·67	2·00
89	·10	4·0	5·76	2·08
77	·10	4·0	5·96	2·17
			5·51	1·96
101	·50	5·7	6·29	2·28
—	·10	4·0	6·40	2·30
—	·10	4·0	6·40	2·36
—	·10	4·0	6·52	2·40
			6·40	2·34

2 — Whirler revolving against sun.

Index Number of Experiment.	Run of Whirler, miles.	Deduct for Mitwind, per cent.	Artificial Wind, miles per hour.	Cups, miles per hour.
19	·45	4·5	2·39	·50
134	·50	4·6	2·54	·64
133	·50	4·6	2·67	·68
76	·10	4·0	2·76	·75
18	·45	4·7	2·86	·73
49	·10	4·0	2·88	·78
			2·68	·68
—	·10	4·0	3·14	·88
53	·10	4·0	3·17	·88
—	·10	4·0	3·20	·91
51	·10	4·0	3·23	·94
55	·10	4·0	3·29	·91
125	·50	4·8	3·25	·87
82	·10	4·0	3·29	·94
126	·50	4·9	3·59	1·08
47	·10	4·0	3·64	1·09
17	·45	5·0	3·80	1·07
88	·10	4·0	3·84	1·21
			3·40	·98
131	·50	5·2	4·56	1·39
132	·50	5·2	4·55	1·41
			4·56	1·40
90	·10	4·0	5·40	1·82
16	·45	5·5	5·67	1·74
14	·45	5·5	5·67	1·87
15	·45	5·5	5·67	1·90
84	·10	4·0	5·96	[illegible]
			5·67	1·86
—	·10	4·0	6·40	2·14
124	·50	5·7	6·43	2·06
78	·10	4·0	6·40	2·13
—	·10	4·0	6·52	2·15
—	·10	4·0	6·52	2·20
103	·50	5·7	6·53	2·11
—	·10	4·0	6·64	2·22
104	·50	5·8	6·78	2·16
			6·53	2·15

Table XIV.—(*Continued.*)

3

Index Number of Experiment.	Whirler revolving with sun. Run of Whirler, miles.	Deduct for Mitwind, per cent.	Artificial Wind, miles per hour.	Cups, miles per hour.
102	·50	5·9	7·06	2·55
85	·10	4·0	7·35	2·68
91	·10	4·0	7·35	2·71
6	·45	6·0	7·52	2·81
7	·45	6·0	7·52	2·72
			7·36	2·69
79	·10	4·0	8·23	3·06
5	·45	6·2	8·45	3·16
			8·34	3·11
44	·10	4·0	9·09	3·44
108	·50	6·3	9·12	3·22
46	·10	4·0	9·34	3·54
109	·50	6·4	9·36	3·43
117	·50	6·4	9·46	3·56
40	·10	6·0	9·60	3·73
118	·50	6·5	9·90	3·64
110	·50	6·4	9·73	3·64
			9·45	3·53
42	·10	4·0	10·17	3·88
4	·45	6·7	11·20	4·32
3	·45	6·8	12·12	4·66
1	·45	6·9	13·03	5·05
2	·45	6·9	13·03	4·99
95	·50	6·9	13·52	5·19
94	·50	7·0	13·61	5·18
93	·50	7·0	13·72	5·23
113	·50	7·0	13·95	5·37
			13·48	5·17
96	1·00	7·0	14·55	5·59
114	·50	7·0	14·55	5·60
			14·55	5·60

4

Index Number of Experiment.	Whirler revolvi Run of Whirler, miles.	Deduct for Mitwind, per hour.
86	·10	4·0
92	·10	4·0
24	·45	6·1
80	·10	4·0
13	·45	6·2
43	·10	4·0
41	·10	4·0
22	·45	6·4
23	·45	6·4
106	·50	6·4
107	·50	6·4
45	·10	4·0
115	·50	6·4
105	·50	6·4
39	·10	4·0
116	·50	6·5
21	·45	6·8
20	·45	6·9
12	·45	6·9
97	·50	7·0
99	·50	7·0
111	·50	7·0
98	·50	7·0
100	1·00	7·1
112	·50	7·1

Some further light is thrown upon this subject by the e conducted by the Cowl Committee at the old Deer Park at Ri the course of their investigation of the action of the wind up of air along open vertical pipes. In the course of these experim

Miniature Robinson Anemometer, 1-in. Cups, $1\frac{3}{4}$-in. Arms.

Experiments by Mr. W. H. Dines, at Oxshott, 1896–7, and Hersham, 1889.

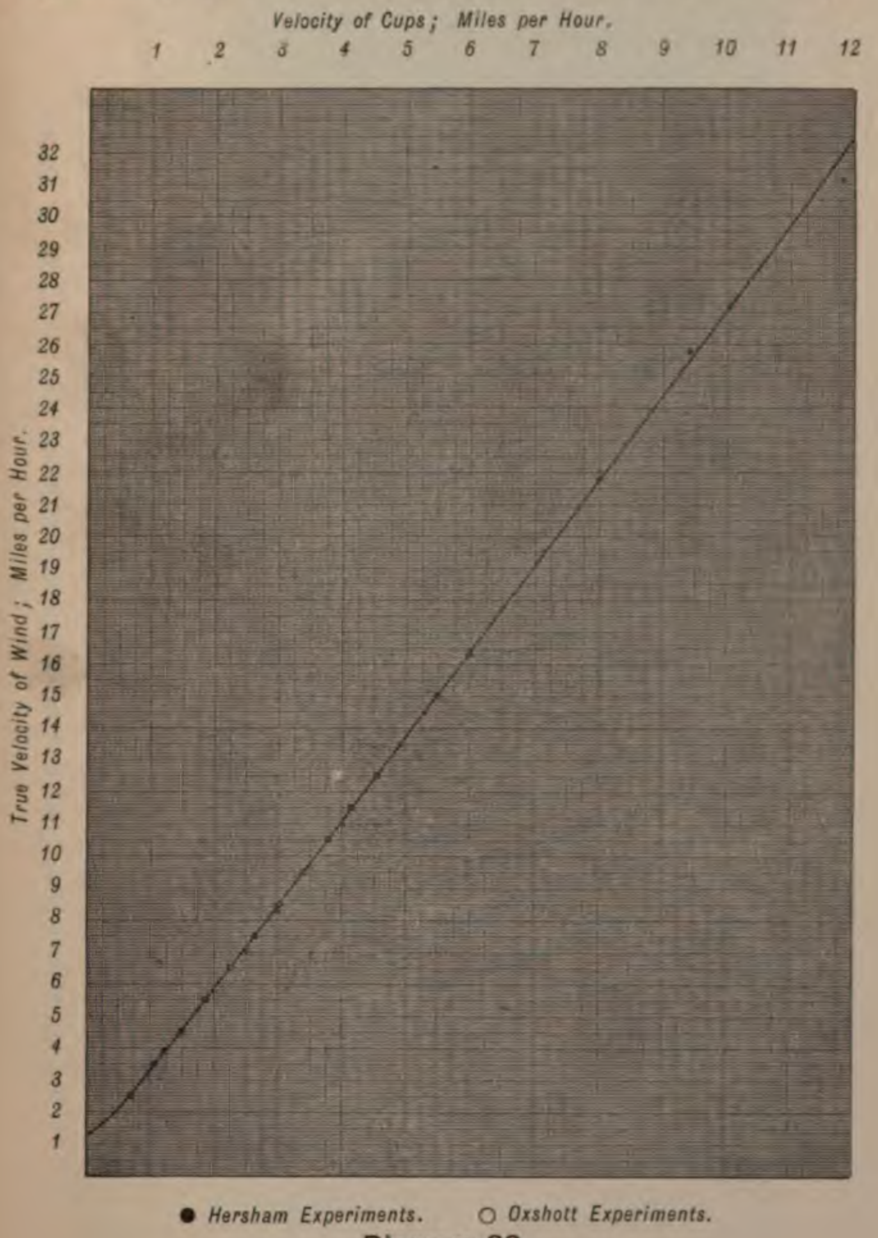


Diagram 23.

Miniature Robinson's Anemometer, 1-inch Cups, 1¾-inch Arms.

Experiments by Mr. W. H. Dines at Oxshott, 1897.

Readings from this Curve have been plotted on Curve of Hersham and Oxshott combined, Diagram 23.

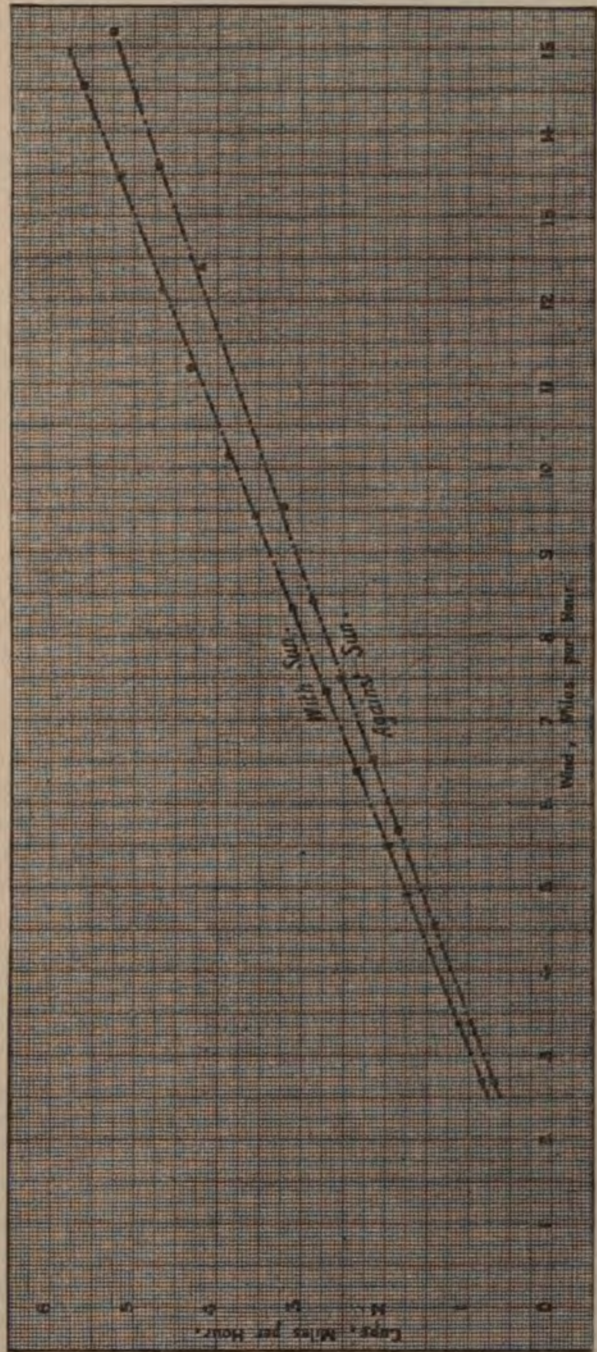


Diagram 24.

in addition to the anemometer, a Dines Pressure Tube had bee
at the Hut, simultaneous readings were obtained from the pre
the Kew Pattern Anemometer, the 1-inch cup instrument, a
same time the flow of air up two of the tubes, which may
the upcast, was also determined. During these experiments
pressure tube occupied the position of the central pipe referr
on, but the upcast for that pipe could be inferred from the f
two outer pipes in a manner which will be explained in the next
this report. It is introduced here only as a basis for the con
the results obtained from measuring the wind velocity by the t
meters and the Pressure Tube, and these results serve to indica
the factors of reduction adopted for the several instruments by
Committee, give concordant measurement of the wind vel
the Hut.

The results are represented, in the first instance, by Table X
is summarised in Table XVI., and the numbers are plotted on Di
p. 286, the curve of which accordingly represents the factors whi
employed to give the actual velocity of the wind (assumed to be
given by the Dines Pressure Tube) from the readings of the tw
mometers and the upcast in the two outside pipes of the Hut resp

A different representation of the same experiments is given in
26, p. 287, where, with the same base line, the actual velocity of
of the two anemometers and the mean upcast velocity of the tw
given by full lines, and on the same sheet, to a different scale a
sented by dotted lines, are given the velocities of the wind der
the two anemometers, using the constants adopted by the C
For the purposes of comparison, a third line showing the v
recorded by the Dines Tube, necessarily a straight line from
struction of the diagram, was plotted on the original diagram, b
reproduced.

It appears from this diagram that the constants from the tw
meters do not give strictly concordant results for the wind veloci
exhibit this divergence more clearly Diagram 27, p. 288, has been
In order to explain this diagram it should be pointed out that if th
of one of the anemometers, the 1-inch cups, be accepted as cor
factors for the other can be derived from the simultaneous readings
factors thus obtained indirectly can be compared with those obt
direct experiment. As the factors for the Kew instrument w
determined by direct experiment for velocities exceeding 13 m
hour, and the factors for the 1-inch cups were determined for
range, the simultaneous readings have been employed to detern

(Continued on p

Table XV.

Comparison of Robinson Cup Anemometers and upcast in the two outside open pipes with Dines Pressure Tube Anemometer.

Ratios arranged according to Wind Velocity as recorded by Dines Pressure Tube.

Index number of experiment.	Velocity of wind by Dines Pressure Tube.	Ratio (Dines). Kew.	1 in. cups.	Upcast. (a)	Upcast. (b)
	Miles per hour.				
7790	4·8	2·23	2·29	2·81	2·87
7729	5·6	2·18	2·21	2·85	2·90
7658	6·0	2·79	2·75	3·30	3·36
7660	6·2	2·19	2·55	3·00	3·07
7657	6·5	2·61	2·79	3·33	3·39
7718	6·4	...	2·79	3·43	3·50
	6·3	2·53	2·72	3·27	3·33
7661	7·0	2·33	2·61	3·14	3·21
7662	7·4	2·67	2·82	3·44	3·52
7659	7·5	2·48	2·82	3·37	3·44
7663	7·7	2·67	2·91	3·57	3·65
7677	7·7	2·36	2·76	3·29	3·36
7727	7·2	2·58	2·73	3·60	3·69
7717	7·3	2·33	2·68	3·33	3.40
7733	7·5	2·24	2·56	3·22	3·28
7719	7·7	2·40	2·70	3·46	3·53
7734	7·8	2·63	2·64	3·63	3·71
7792	7·6	2·33	2·67	3 23	3·30
	7·5	2·46	2·72	3·39	3·46
7664	8·3	2·40	2·92	3·54	3·61
7666	8·8	2·46	2·80	3·50	3·57
7667	8·2	2·59	2·85	3·57	3·65
7720	8·7	2·31	2·72	3·53	3·60
7721	8·7	2·21	2·72	3·42	3·48
7722	8·8	2·74	2·82	3·85	3·93
7725	8·5	2·71	2·71	3·70	3·78
7726	8·7	2·56	2·72	3·61	3·68
7728	8·8	2·56	2·75	3·72	3·79
7730	8·4	2·32	2·66	3·44	3·50
7731	8·7	2·80	2·88	3·99	4·07
7732	8·6	2·74	2·76	...	...
7743	8·3	2·77	2·89	3·71	3·78
7746	8·8	2·55	2·98	3·70	3·78
7766	8·8	2·74	3·00	3·78	3·81
7776	8·4	2·37	2·91	3·50	3·57
7789	8·6	2·47	2·90	3·67	3·75
	8·6	2·55	2·76	3·64	3·71
7626	9·0	2·86	...	...	3·88
7628	9·9	2·87	...	4·00	4·07
7640	9·3	2·74	...	3·79	3·86

Index number of experiment.	Velocity of wind by Dines Pressure Tube.	Ratio (Dines) Kew.	1 in. cups.	Upcast. (a)	Upcast. (b)
	Miles per hour.				
7669	9·2	2·44	2·86	3·57	3·64
7716	9·0	2·42	2·94	3·65	3·72
7724	9·8	2·58	2·79	3·78	3·87
7775	9·9	2·42	2·98	3·71	3·79
7778	9·2	2·40	2·96	3·70	3·77
7779	9·9	2·25	2·95	3·69	3·77
7780	9·8	2 76	3·24	3·92	3·99
7787	9·4	2·24	2·85	3·53	3·61
7791	9·1	2·36	2·86	3·62	3·69
	9·5	2·53	2·94	3·72	3·80
7665	10·1	2·50	2·99	3·72	3·80
7668	10·0	2·41	2·95	3·67	3·74
7676	10·6	2·28	2·84	3·60	3·67
7679	10·5	2·45	3·01	3·95	4·03
7723	10·7	2·66	2·80	3·80	3·88
7736	10·2	2·91	2·94	4·06	4·14
7744	10·0	2·76	3·04	4·07	4·15
7748	10·5	2·91	2 97	4·09	4·18
7768	10·0	2·52	3·15	3·84	3·93
7784	10·3	2·32	2·89	3·67	3·75
	10·3	2·57	2·96	3·85	3·93
7672	11·5	2·38	2·94	3·67	3·83
7674	11·9	2·45	2·94	3·70	3·78
7680	11·9	2·33	2·97	3·86	3·94
7737	11·0	2·87	3·08	4·30	4·38
7738	11·5	2·58	2·92	3·85	3 93
7753	11·8	2·50	2·88	3·75	3·83
7761	11·8	2·55	2·70	3·84	3·89
7763	11·5	2·49	3·12	4·05	4·10
7764	11·0	2·73	3·22	4·08	4·17
7765	11·4	2·45	2·96	3·74	3·81
7770	11·6	2·49	3·09	3·93	4·00
7772	11·8	2·41	3·02	3·80	3·87
7774	11·1	2·43	2·90	3·77	3·85
7781	11·9	2·28	2 94	3·71	3 79
7782	11·5	2·20	2·92	3·64	3·72
7785	11·7	2·45	3·13	3·87	3·95
7786	11·0	2·36	2·95	3·74	3·81
7788	11·0	2·33	2·88	3·80	3·87
	11·5	2·46	2·98	3·84	3·92
7632	12·7	2·71	...	4·27	4·35
7641	12·9	2·52	...	3·91	4·00
7652	12·5	2·84	...	4·21	4·30
7673	12·7	2·31	2·86	3·76	3·84

Table XV.—(*Continued.*)

Comparison of Robinson Cup Anemometers and upcast in th
open pipes with Dines Pressure Tube Anemometer

Ratios arranged according to Wind Velocity as recorded by Dines I

Index number of experiment.	Velocity of wind by Dines Pressure Tube.	Ratio (Dines).			
		Kew.	1 in. cups.	Upcast. (*a*)	Upcast. (*b*)
	Miles per hour.				
7681	12·5	2·40	2·97	3·89	3·97
7742	12·4	2·92	3·00	4·23	4·31
7745	12·2	2·71	3·03	4·05	4·13
7747	12·9	2·84	3·04	4·25	4·33
7754	12·6	2·40	2·84	3·76	3·80
7755	12·9	2·57	2·92	3·86	3·94
7767	12·2	2·56	3·07	3·95	4·02
7771	12·2	2·62	3·16	4·20	4·28
7773	12·7	2·45	2·89	3·76	3·84
	12·6	2·60	2·98	4·01	4·09
7629	13·8	2·63	...	4·07	4·16
7670	13·0	2·41	2·97	3·84	3·92
7671	13·4	2·44	3·06	4·00	4·08
7675	13·0	2·31	2·85	3·64	3·71
7678	13·9	2·33	2·93	3·83	3·91
7708	13·9	2·69	...	4·00	4·08
7739	13·5	2·63	2·89	3·97	4·05
7760	13·8	2·54	2·98	3·92	3·99
7762	13·5	2·45	2·96	3·88	3·92
7769	13·0	2·37	2·79	3·71	3·79
7777	13·2	2·50	3·08	4·03	4·12
	13·5	2·48	2·95	3·90	3·98
7643	14·0	2·59	...	4·11	4·19
7653	14·8	2·55	...	4·11	4·19
7655	14·3	2·63	...	4·18	4·26
7686	14·3	2·68	3·12	4·02	4·10
7688	14·4	2·64	...	3·98	4·06
7696	14·0	2·58	...	3·90	3·97
7713	14·7	2·70	...	4·26	4·34
7749	14·8	2·75	2·98	4·20	4·28
7759	14·0	2·45	2·83	3·79	3·83
	14·4	2·62	2·98	4·06	4·14
7630	15·4	2·77	...	4·18	4·26
7634	15·9	2·58	...	4·15	4·24
7642	15·4	2·60	...	4·20	4·27
7651	15·6	2·60	...	4·09	4·17
7685	15·3	2·60	...	3·90	3·98
7690	15·1	2·64	...	3·94	4·03
7692	15·8	2·65	...	3·90	3·98
7693	15·8	2·62	...	3·89	3·97
7695	15·7	2·50	...	3·82	3·89
7704	15·3	2·55	...	3·97	4·05
7706	15·3	2·55	...	3·88	3·96
7710	15·9	2·58	...	4·10	4·19

Index number of experiment.	Velocity of wind by Dines Pressure Tube.	Kew.	1 c
	Miles per hour.		
7711	15·2	2·62	
7712	15·5	2·66	
7741	15·7	2·59	2
7751	15·8	2·75	2
	15·5	2·62	2
7635	16·5	2·58	.
7650	16·4	2·59	.
7683	16·3	2·57	.
7684	16·3	2·59	.
7694	16·5	2·51	.
7709	16·5	2·56	.
7752	16·2	2·81	2·
	16·4	2·60	2·
7644	17·6	2·54	.
7645	17·2	2·53	.
7682	17·0	2·22	2·
7687	17·4	2·64	.
7699	17·8	2·50	.
7705	17·3	2·51	.
7740	17·0	2·61	2·
7757	17·2	2·58	2·
	17·3	2·52	2·
7636	18·4	2·57	.
7638	18·8	2·46	.
7646	18·9	2·54	.
7648	18·5	2·54	.
7689	18·1	2·58	.
7702	18·5	2·46	.
7707	18·6	2·55	.
	18·5	2·53	.
7647	19·2	2·51	.
7649	19·9	2·58	.
7691	19·5	2·48	.
7697	19·5	2·50	.
7698	19·4	2·54	.
	19·5	2·52	.
7701	20·0	2·34	.
7703	20·5	2·47	.
	20·3	2·40	.
7637	21·5	2·50	.
7700	21·5	2·51	.
	21·5	2·51	.

Note.—(*a*) is Upcast with no correction for direction of wind; (*b*) is Upcast with a corr direction of wind. Calculated as described in Part IV.

LOW VELOCITIES.

In plotting the diagrams for "Upcast" flow, compared with the different instruments for measuring the velocity of the wind, no entry occurs of a less velocity than about 100 feet per minute, so that experiments made with a less velocity may be supposed to have been disregarded. This gives a flow of about the same magnitude in the upcast of the central pipe.

In tabulating the results for cowls, the smallest value taken for the readings of outside pipes is 58. For these experiments the rule adopted was to reject any result when there was less wind than that corresponding to 9 revolutions per minute of the cups.

The compass diagrams in Part IV. include fifteen experiments with very low velocities between 0 and 100, but the results are very uncertain and are marked by Mr. Field as unreliable.

Table XVI.

Comparison of Robinson Cup Anemometers and upcast in the two outside open pipes with Dines Pressure Tube Anemometer.

Experiments made at the "Hut," Old Deer Park, Surrey.

Wind velocity by Dines Pressure Tube.	Number of experiments averaged.	Dines. ÷ Kew pattern.	Dines. ÷ 1 in. cups.	Dines. ÷ Upcast. (a)	Dines. ÷ Upcast. (b)
1	2	3	4	5	6
Miles per hour.					
4·8	1	2·23	2·29	2·81	2·87
5·6	1	2·18	2·21	2·85	2·90
6·3	4	2·53	2·72	3·27	3·33
7·5	11	2·46	2·72	3·39	3·46
8·6	17	2·55	2·76	3·64	3·71
9·5	12	2·53	2·94	3·72	3·80
10·3	10	2·57	2·96	3·85	3·93
11·5	18	2·46	2·98	3·84	3·92
12·6	13	2·60	2·98	4·01	4·09
13·5	11	2·48	2·95	3·90	3·98
14·4	9	2·62	2·98*	4·06	4·14
15·5	16	2·62	2·93†	4·01	4·10
16·4	7	2·60	2·98‡	4·07	4·15
17·3	8	2·52	2·84*	3·96	4·04
18·5	7	2·53		4·03	4·11
19·5	5	2·52		3·95	4·03
20·3	2	2·41		3·71	3·77
21·5	2	2·51		3·95	4·01*

* Three experiments only; † two experiments only; ‡ one experiment only.

NOTE.—(*a*) is Upcast *without* correction for direction of wind; (*b*) is Upcast *with* correction for direction of wind.

From detailed Table, dated October 12th, 1900.

Robinson's Cup Anemometer.

Diagram of Factors of Reduction (illustrating Table XVI.)

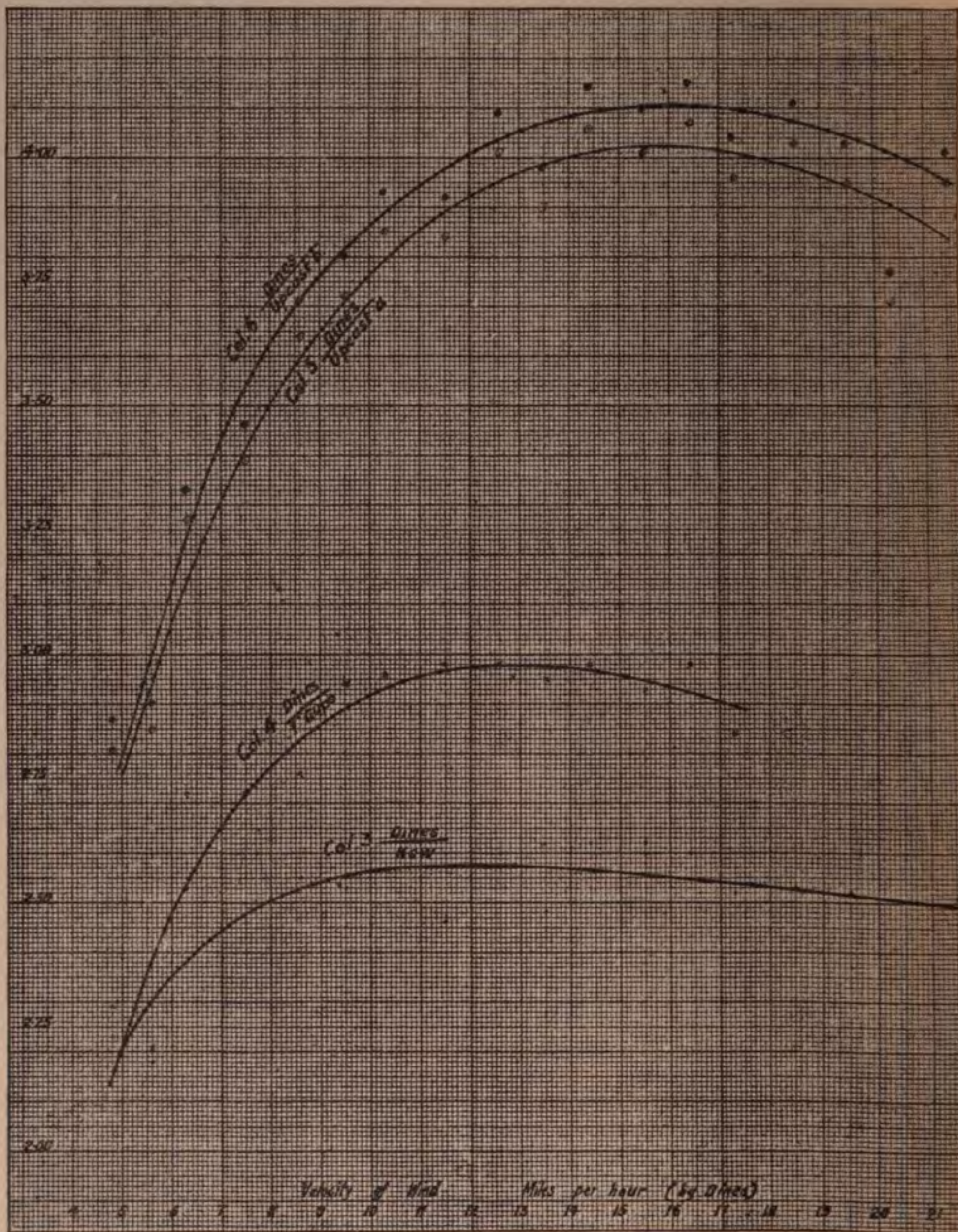


Diagram 25.

Robinson's Cup and Dines' Pressure Tube Anemometer compared with Upcast in the centre Pipe.

Experiments at the Hut, Old Deer Park, Richmond, Surrey.

Results of Simultaneous Readings (illustrating Table XVI.)

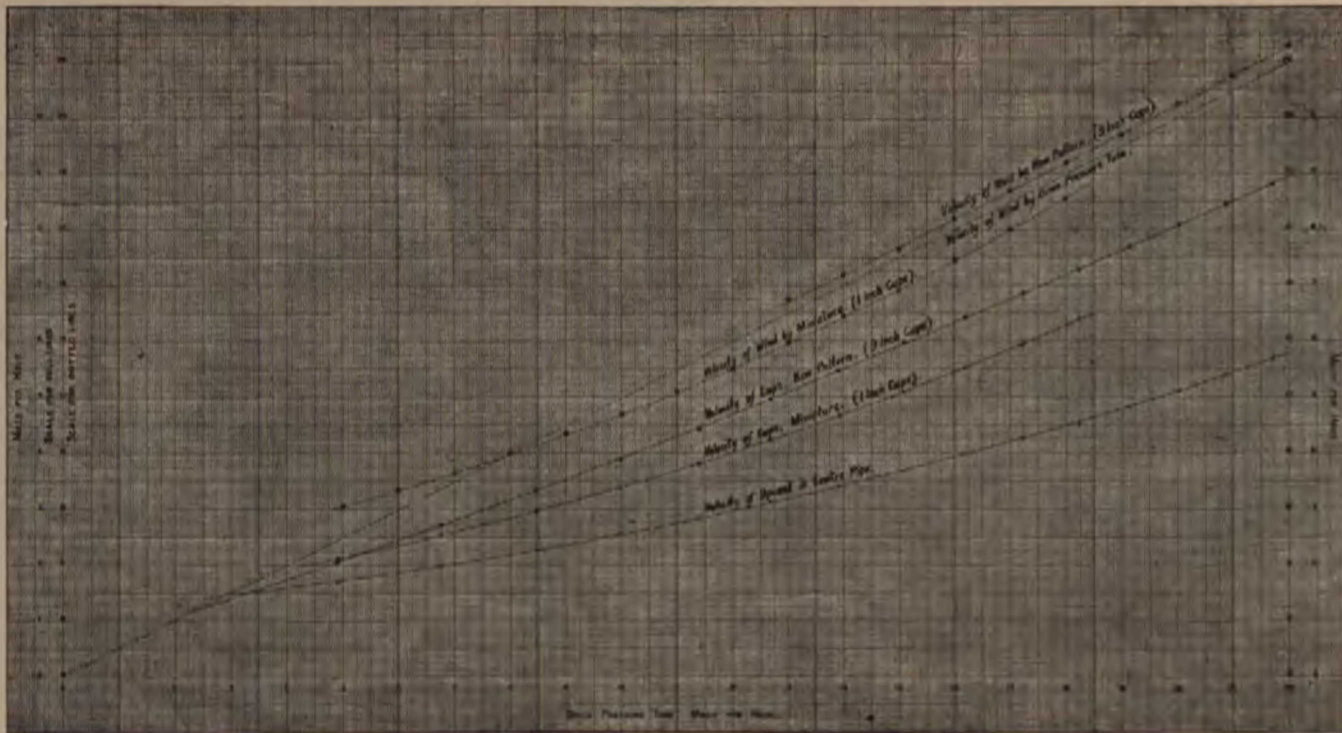
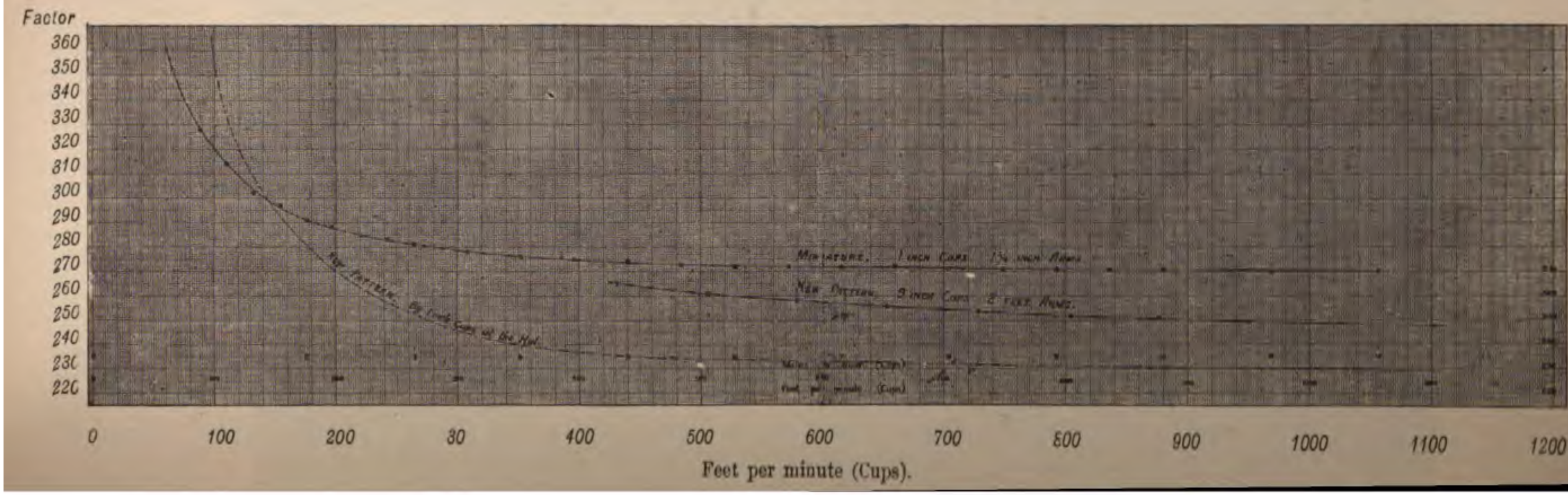


Diagram 26.

NOTE.—No factors for the Kew pattern Anemometer have been obtained for winds below thirteen miles per hour.

Robinson's Cup Anemometers.

Factors for Kew Pattern and Miniature.



factors of the Kew Pattern instrument over the wider range, and these factors corresponding to a given run of the cups have been set out on the diagram in the lower dotted line, while the factors for the 1-inch cups and the factors for the Kew Pattern over the limited range of direct experiment are shown by full lines. The divergence between the factors of the Kew Pattern instrument, as determined indirectly and by direct experiment, is thus clearly shown.

With regard to this diagram it should be noticed that the Kew anemometer was erected at one end of the Hut and the 1-inch cups at the other end, while the Dines pressure tube replaced the centre pipe (see Diagram 18, page 262). The divergence between the readings shown on the diagram must therefore not be regarded as necessarily due to errors in the factors of the anemometers. It may be due, to an extent which is unknown, to the difference of position of the instruments, and it is to be noticed that the mean of the plotted wind velocities as derived from readings of the Kew Pattern and the 1-inch cups (see Diagram 26, p. 287) agrees with the Dines reading within about 2 per cent., which is not an extraordinary estimate of the difference of upcast between the centre pipe and the mean of the outside pipes, as detailed in a subsequent chapter. For these the differences of exposure were not so great as in the case of the two anemometers.

Simultaneous observations of the upcast and anemometer readings were made in 1895 and again in 1898. In what has already been said, the results of the two sets of experiments have been combined, and it has not been regarded as necessary to treat them separately; but in the final Diagram 28, p. 291, referring to this part of the subject, the results of the separate series of experiments are separately indicated. This Diagram may be regarded as embodying all the results of the Committee's work upon the determination of wind velocities.

As base line in this diagram the upcast is taken—it may be either the upcast in the central pipe if that was free for the purpose of observation, or the mean of the two outside pipes if the central pipe was occupied by the Dines pressure tube. The observations corresponding to the separate curves are indicated on the diagram itself, and the differences of ordinate indicate the amount of divergence of the different measures of velocity. It should be noted that these divergencies include not only what is due to the uncertainties arising from any want of accuracy in the constants of the instruments and from any peculiarity of position, but would also be affected by any errors arising from uncertainties in the reading or computation of the upcast. Under these circumstances the divergences which do not amount to more than two miles per hour in the values of the wind

velocity, indicate as satisfactory an agreement as could be
they point to the exercise of great care in the working of the
and the arrangement of the experiments.

To test the effect of changes of winds and gusts upon the
anemometers, and the air-meter in the upcast pipe, Mr. Pegg
and 28th June, 1895, arranged a number of simultaneous re
three instruments for successive intervals of half a minute
observations with the Kew Pattern instrument were made; t
1 inch cup anemometer indicate that it is somewhat more
rapid changes in the velocity of the air, than the meter in the
is only what might be expected on account of the inertia of t
tube, which has no counterpart in the measurements with the
and which would tend to make the flow in the tube perma
cases of the flow of fluid along a pipe of greater or less l
results for neither instrument are reduced to actual flow o
observations were plotted by Mr. Peggs, and are preserved w
papers, but are not reproduced here.

Observations were also made with Hagemann's anemomete
de l'Institut Météorologique Danois, 1876) for the purpose of
instrument, two specimens of which were obtained for the co
depends for its action upon the diminution of pressure produce
ing over the mouth of a tube, but after a few trials the instrum
further used. A similar principle has since been applied in
Pressure Tube anemometer.

Experiments on Candle Flames.

In order to be able to measure the velocity of very light
air, experiments were made with candle flames. The flames
by the air discharged from a gas holder. The actual vel
current was determined by calculation of the amount of air
the gas holder in a measured interval of time. Two method
for obtaining the reading of the inclination of the flame.
method the candle formed a continuation of a movable arm
over a graduated quadrant from the vertical, and the readin
when the flame exposed to the draught, and the arm support
in line; and secondly, the candle was held vertically and the
of the flame measured with a clinometer. Diagram 29 is a s
form of the first arrangement. The candle was a sperm stan
for gas testing. The results are given in Tables XVII. and
293-294.

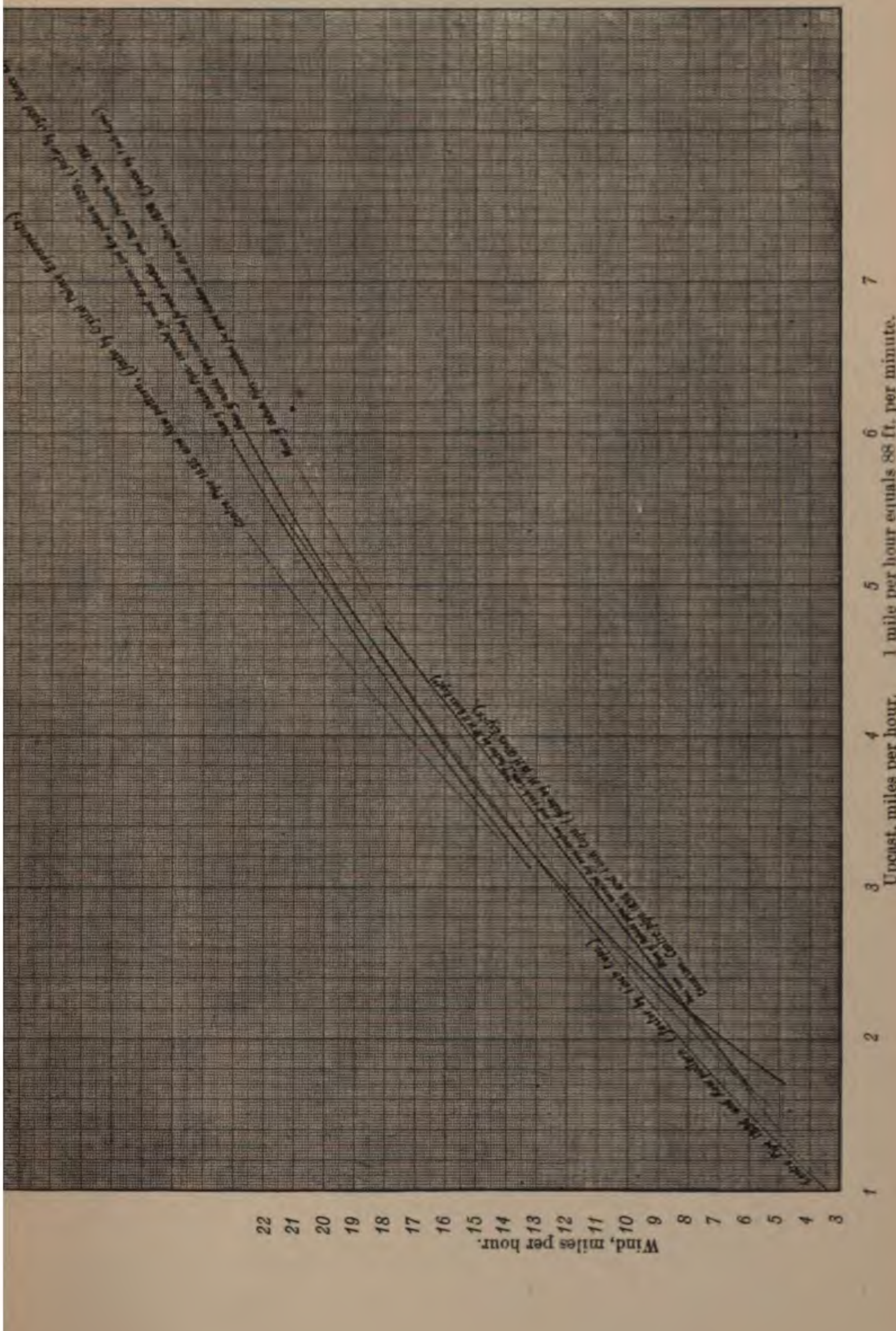

Wind, miles per hour.
3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
Upcast, miles per hour. 1 mile per hour equals 88 ft. per minute.
1 2 3 4 5 6 7

Diagram 28.

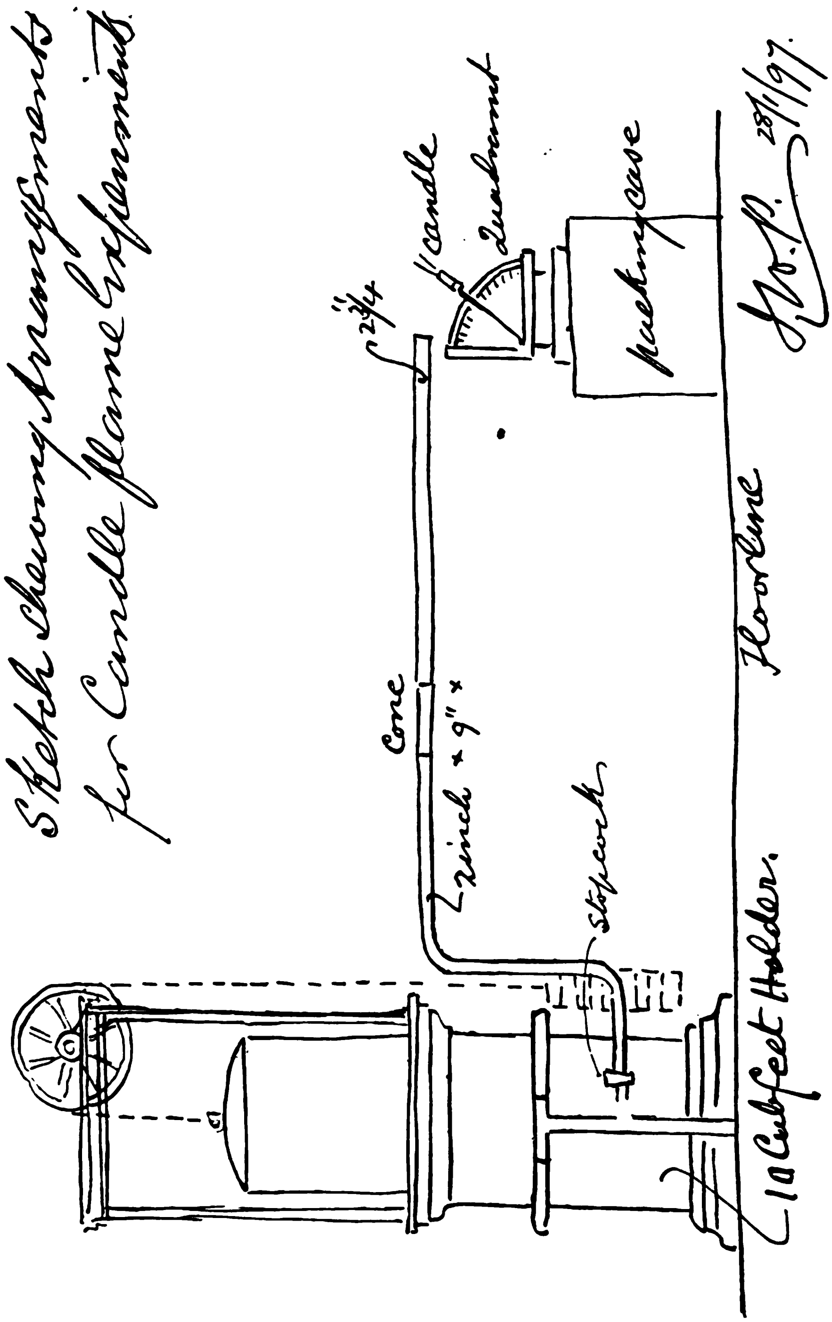

Sketch showing Arrangements
for Candle flame Experiments.
2¾"
candle
Quadrant
packing case
Cone
2 inch × 9"
stopcock
10 Cub feet Holder.
Floor line
28/1/97.

Diagram 29.

Table XVII.—Candle Flame Experiments.

CLINOMETER. *PLOTTED ⊙ ON DIAGRAM 30.*

No.	Velocity, feet per min.	Angle from Vertical.
1	20·49	7°
	20·98	9
	20·74	9
2	20·01	10
	21·23	10
	21·47	10
5	26·80	15
	26·35	14
	26·35	14
6	26·35	14
	26·84	14
	27·57	13
	23·18	13
	25·37	16
	25·86	16
	23·97	12·3
	31·72	10
4	33·67	10
7	38·06	22
	36·84	22
	36·60	22
8	37·33	26
	34·89	27
	36·35	27
	37·08	27·5
	36·60	33
	36·60	34
	36·60	33
	36·60	33
	36·60	34
	36·60	33
	36·14	26·2
9	48·55	35
	47·82	31
	49·00	36
10	46·36	32
	47·33	31
	47·91	32
	48·31	32
	47·58	31
	49·78	43
	42·70	30
	45·87	30
	49·78	38
	45·38	34
11	49·53	38
	48·07	37
	48·55	37
	47·66	34·2

No.	Velocity, feet per min.	Angle from Vertical.
	57·07	44°
10	53·19	32
	52·46	32
	52·21	32
	51·73	33·5
	54·17	39
13	53·19	39
	53·19	38
	53·19	37·5
	53·19	37·5
14	59·54	47
	53·92	37·4
14	65·88	44
	61·73	46
	61·48	45
	61·00	47
	61·73	49
18	65·88	54
	62·95	47·5
15	73·20	45·5
	71·98	48
	71·98	48
	71·98	48
	71·98	52
	71·98	53
16	71·98	51
	71·98	49
	71·98	50·5
	71·98	50·5
17	73·69	50
	73·20	51
	73·20	51
	72·71	50
21	73·93	57
	77·59	56
	76·61	55
	73·06	50·9
12	85·40	57
19	86·86	56·5
	86·13	55
	85·40	55
	85·15	51
	85·40	52
	85·40	61
	84·18	60
	85·40	55
	83·45	52
	85·88	53
	85·40	54
	85·40	57·5
	85·40	56

No.	Velocity, feet per min.	Angle from Vertical.
19	85·88	58°
	85·40	55
20	85·89	55
	84·18	56
	86·38	54
	85·40	55
29	87·11	66
	86·38	63
	85·89	61
	86·38	62
	85·57	56·7
22	97·60	58·5
	96·38	57·5
	97·60	57
	95·62	57·5
23	98·82	60
	92·72	57
	93·94	57·5
25	95·16	60
	93·45	59
28	91·01	60
	95·33	58·4
22	100·40	58·5
23	100·28	59
	101·02	60
25	101·26	62
	100·40	60
24	102·48	59
27	108·82	60
28	107·60	60
	108·82	61
	105·92	61
	105·51	61·5
	103·86	60·2
27	114·49	67
	110·29	62
	110·37	60
	110·04	62
	110·04	62
28	113·70	68
	119·56	66·5
31	118·58	72
	113.38	64·9
28	120·30	67
26	120·78	61·75
	120·78	61
31	126·88	75
	122·19	66·2
30	149·33	65
	152·25	65
	150·79	65

Table XVIII.—Candle Flame Experiments.

QUADRANT. *PLOTTED ● ON DIAGRAM 30*

No.	Velocity, feet per min.	Angle from Vertical.
32	16·59	9°
	16·59	9
	16·10	9
	18·30	11
33	19·52	13
	19·52	11·5
	19·52	10
	18·02	10·4
33	20·35	9·5
	20·49	10·0
35	20·74	14·0
	22·45	13
34	22·69	11
	26·84	14
	26·35	14
36	25·37	15
	25·37	16
37	26·80	15
	26·80	16
	26·80	16·5
38	25·37	16
	29·77	20
	29·52	20
	30·50	20
	29·52	20
39	26·84	25
	25·62	25
	28·80	26
42	24·90	26
	24·90	26
	25·76	17·6
40	36·60	25
	36·11	25
	36·11	25
	37·57	25
41	38·31	26
	36·35	26
	35·86	25
43	33·67	32
	34·16	32
	34·65	32
	35·60	31
45	39·00	36
	36·17	28·3

No.	Velocity, feet per min.	Angle from Vertical.
47	42·00	38°
48	47·58	41
46	48·07	46
46	47·82	33
46	48·31	33
44	48·80	32
44	49·53	32
	47·44	36·4
46	54·90	33
	50·75	33
48	50·02	45
44	50·02	32
	50·75	38
	55·87	41
49	53·68	44·5
	53·68	45
	53·68	44
	57·34	49
	53·07	40·45
46	69·54	40
50	61·00	44
	62·71	45
	61·97	46
	61·00	45
	62·46	44
	62·71	44
	62·71	45
51	61·00	50
	60·50	51
	60·50	51
	62·57	45·9
51	75·64	55
	75·64	54
52	75·15	50
	74·18	55
	74·90	55
	75·15	55
	75·15	55
46	70·76	43
	72·95	39
	74·39	51·2

No.	Velocity, feet per min.	Angle from Vertical.
53	87·35	57°
	87·11	57
	87·23	57
53	93·94	58
	92·47	58
54	97·60	60
	97·60	58
	93·94	59
	95·89	60
	97·60	60
	97·60	60
55	97·60	59·5
	96·03	59·2
55	122·00	62
	122·00	61
	122·49	62
	122·00	61·5
	120·78	62
	120·29	62
56	124·40	62
	115·90	62
	119·56	67
	121·05	62·4

These results, given in Tables XVII. and XVIII., are represented on the following curve :—

Experiments on Measurement of Air Currents by Candle Flame, 1879.

NOTE.—By Clinometer shown thus ⊙ ; by Quadrant shown thus ● The figures against each plot indicate the number of experiments averaged.

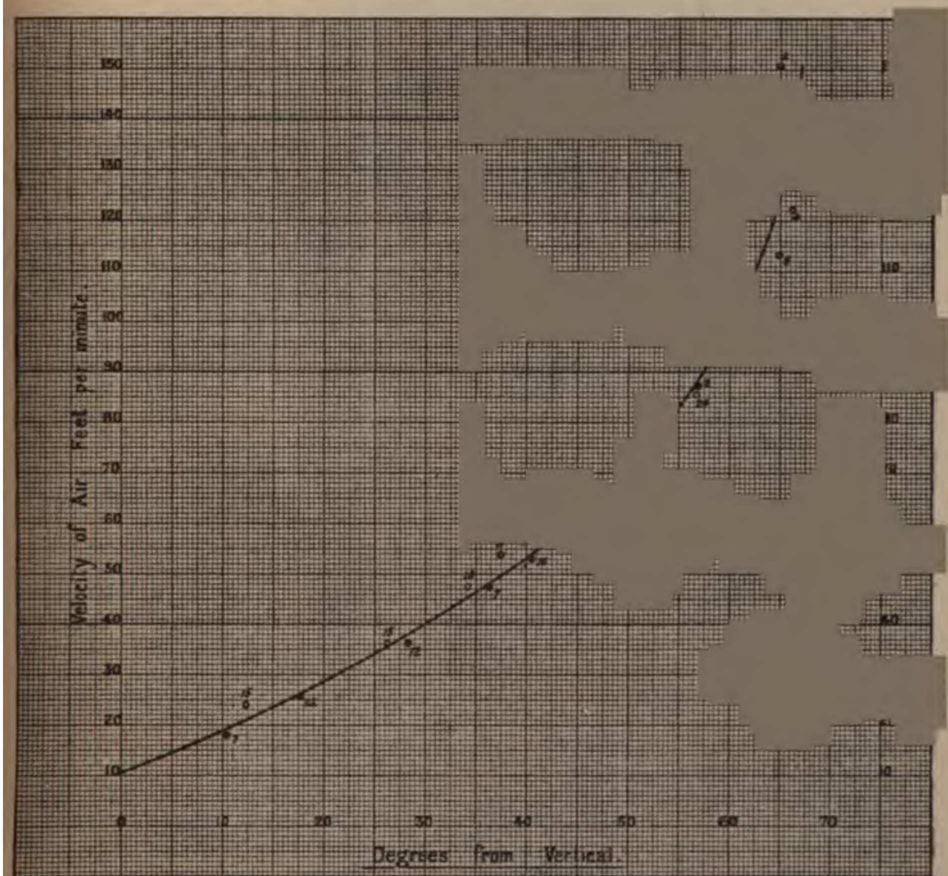


Diagram 30.

Sir Douglas Galton had previously given in his "Healthy
the following table :—

Velocity of flow of air Feet per second.	Angle of inclination of flame of candle with horizon.
1·6	30°
1·0	40°
0.75	50°
0.50	60°
0·40	65°

These experiments were intended to furnish a means of
the lowest velocity of air which would move the cups of the sm
anemometer.

By the use of the method the minimum current required
cups was found to be 1·7 feet per second; a walking test in
Field's office, at 7, Victoria Street, gave 1½ feet per second.

PART IV.—COMPARISON OF THE FLOW OF AIR THROUGH OPEN TUBES.

The Experiments at the Hut in the Old Deer Park.

The regular experiments at the hut in the Old Deer Park were mainly of three types, viz., "Upcast," "Down-draught," and "Injector."

In the Upcast experiments three galvanized iron pipes were fixed in an upright position so as to project through the roof of the hut and through the platform above it, terminating about 4 ft. 6 in. above the level of the platform. Three 4-ft. lengthening pieces of zinc were fixed on the top of these galvanized iron pipes, and the cowl or terminal to be tested was fixed in an upright position on the centre pipe. The positions of the pipes and of the Robinson Cup Anemometer are shown in the drawing on Diagrams 15—19, pages 256 and 261.

In the Down-draught experiments only the centre pipe was made use of, and the cowl or terminal to be tested for down-draught was fixed on it by means of an elbow tube (figs. 8 and 9). This arrangement enabled the cowl or terminal to be inclined at different angles, either towards the wind, so as to represent wind blowing downwards, or from the wind so as to represent wind blowing upwards; a separate elbow tube was used for each different angle.

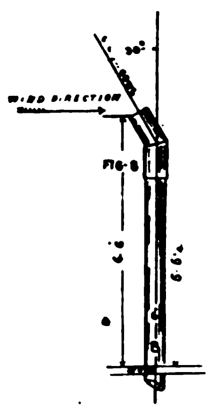


FIG. 8.

Pipes arranged for downdraught tests ready to receive the Cowls (angles varied)

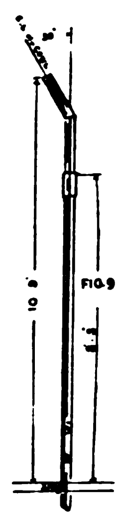


FIG. 9.

Besides these experiments upon Cowls or Terminals inclined to or from the wind, subsidiary down-draught experiments were tried upon Cowls or terminals fixed on a pipe in an upright position with a board at different distances behind (see p. 439). The object of these experiments was to ascertain the circumstances under which a down-

draught would be caused in the pipe if the wind were obstru board placed in the position experimented on.

In the Injector experiments the three upright pipes allude were made use of. The Injector to be tested (whether cowl or was fixed in an upright position on the centre pipe so that th downcast in the centre pipe and an upcast in the two outside pip

The large majority of the tests consisted of Upcast experim were of three kinds, viz., upon Open Pipes, Cowls, and Termina

A pipe is called an "Open Pipe" whether it is straight or course, provided that the termination exposed to the wind is transverse section of the pipe. For the larger number of the e all three pipes were used, and they were straight open pipes vertically, but for the special experiments on down-draught pipe (the centre pipe) was used, and it was a plain open pip elbow about 2 ft. 6 in. from the orifice.

A "Cowl" is any contrivance sold by manufacturers for the automatically producing or improving the flow of air in a pip Cowl experiments the cowl was fixed on the centre pipe, an outside pipes were left plain open pipes.

"Terminal" is the name originally given to slight modificat shape of the orifice of a pipe for experimental purposes, but it has been extended to include more elaborate modifications of and appendages added for experimental purposes. In termin ments the terminal was fixed on the centre pipe, and the two ou were left plain open pipes.

The experiments on Open Pipes were further sub-divided ac the size of the pipes 3 in. or 6 in., and according to the perio the experiments were tried. The reference "early experiment to those prior to November, 1894, and "later experiments" subsequent to that date, when the experiments were of a more t character in consequence of the experience gained from the earl

The line along the hut in which the pipes were placed was f W. to N. by E., or roughly South and North, as shown o 17, p. 261. For convenience of reference the South Pipe is referred to as Pipe A, the Centre Pipe as Pipe B, and the Nor Pipe C.

The whole number of experiments at the Old Deer Park e about 9,000, including all experiments on Open Pipes, Cowls, and These were entered on a specially prepared form, which has beco as the "*Complete Tabulation.*" In it the results are grouped ac

the type of terminal or cowl that was the subject of experiment, and the form of entry is similar in the case of Open Pipes. The tabulation provided for the entry of the day and hour of the experiment, its duration, the temperature at three points, the wind direction, the run of the anemometer, the readings of the air meters, the upcast velocity deduced from the readings of the air meters by the standard curves already described with a column for remarks indicative of special circumstances that were noticed at the time of the experiment.

In the case of Open Pipe experiments columns were provided for the mean of the outside pipes A and C, and for the percentage difference between that mean and the reading of the pipe B, which was called the standard. The form of the tabulation was slightly modified to provide for the case of Cowls and Terminals. A specimen of the Complete Tabulation of experiments on one particular form of terminal, viz., that which gave the best average numerical result, is reproduced in a later section of this report, p. 396, and may be referred to as indicating the modification of the form of the complete tabulation for cowls and terminals.

Of the 9,000 experiments a very considerable number were rejected by Mr. Rogers Field, some in accordance with general rules laid down, and others after personal inspection. So far as Open Pipe experiments are concerned, the general principles were to reject (1) all later experiments which corresponded with an anemometer reading below nine revolutions of the cups per minute, (2) experiments in which the upcast velocities in the pipes A and C showed a difference of 10 per cent. Besides experiments rejected on these grounds, a number were discarded because they were regarded at the time as being for some reason unsatisfactory. The cause of rejection is given in each case in the remarks column of the Complete Tabulation. Of the 1,037 experiments on open pipes 238 in all were rejected, 15 on account of the low velocity of the wind, 68 on account of the difference between the readings of the outside pipes, and 155 at the discretion of the experimenter subsequently confirmed by Mr. Rogers Field.

The Complete Tabulation of the experiments on Open Pipes contains the results of the upcast experiments, the down-draught tests with pipe inclined from the vertical, and the tests for down-draught due to a board behind the terminal.

An index number was given to each experiment as a means of reference because the classification of the results necessitated the averaging of large numbers of experiments taken on various dates. From the recorded revolutions of the Robinson cups during the interval of each experiment,

the run of the cups in feet per minute was determined and ent
table. The direction of the wind was entered as in the origin
many cases verified by comparison with the wind records at the K
vatory as explained later. The registration shown on the dial o
air meters which recorded the upcast in the three pipes was r
means of the Standard Curves, Diagrams 5 and 6, p. 235, a
method described on p. 233, to actual velocity in lineal feet per
3-in. pipe. The percentage differences between the mean upc
two outside pipes and that in the centre pipe were then calcu
bringing the whole of the open pipe tests on to a comparable bas

Only a few Open Pipe experiments were made for down-drau
results were entered on a specially prepared form of tabulatio
be referred to in Part V. of the report.

Wind Direction.

In order to determine the direction of the wind in the
the experiments, a light flag of cotton waste fibre was used.
was attached to the top of an iron rod which stood on a comp
and the whole apparatus was placed about 20 feet away from
on the windward side. A similar contrivance was also fixe
platform above the Hut at the North end of it. The directi
latter case was identified by landmarks taken from the Ordna
For carrying out the experiments the duty was divided bet
observers, one inside the hut who read the air meters, and
outside who determined the direction of the wind. If there
difference exhibited between the flag on the Hut and that on t
the indication of the former was adopted.

In order to check the determinations of wind direction, the
tions in about 1,500 cases were compared with simultaneous re
the anemograph at Kew Observatory. The cases originally se
comparison were those in which there were abnormal differences r
in the upcast readings. Later on it became the practice to keep
comparison between the Observatory readings and the observatio
Hut. In all 3,000 such additional wind readings were taken. Th
was continued until the death of Mr. E. Dagwell, a member o
of Kew Observatory, made it impracticable to continue the comp

There are a few cases in which the observations at the Hut d
those at the Observatory by as much as two points of the compas
On one occasion with a light wind there was as much as 90° of
between the two, but for the most part the agreement between
ings at the two stations was quite satisfactory.

In those cases where there was any important difference, the reading was corrected in accordance with a code of rules drawn up by Mr. Rogers Field, or the cases were referred to Mr. Field for decision. It may be understood that the wind directions are not held to be accurate to within one point of the compass.

Results of the Open Pipe Tests.

The initial question to which the Committee applied themselves was to determine in what way an Open Pipe Standard could best be obtained with which to compare the upcast velocity in the centre pipe when a cowl or terminal was placed upon it. To do this it was necessary to ascertain how the upcast in the central Open Pipe could be inferred from the upcasts in the two outside Open Pipes. For this purpose a comparison was made between (1) the upcast velocity in the centre pipe B corrected by means of the revised standard curves described at pages 235, 236 and 265, and (2) the mean of the upcast velocities (similarly corrected) in the two outside pipes A and C, and the differences per cent. between the two were calculated for the early experiments. The percentage differences were entered in separate columns on the sheets of the Complete Tabulation according to whether they were positive or negative. As they were very irregular, tables were prepared in which the differences per cent. were arranged according to the direction of the wind, and all the differences, positive and negative, were averaged algebraically for each point of the compass. The manner in which these tables were prepared will be seen from the appended example:—

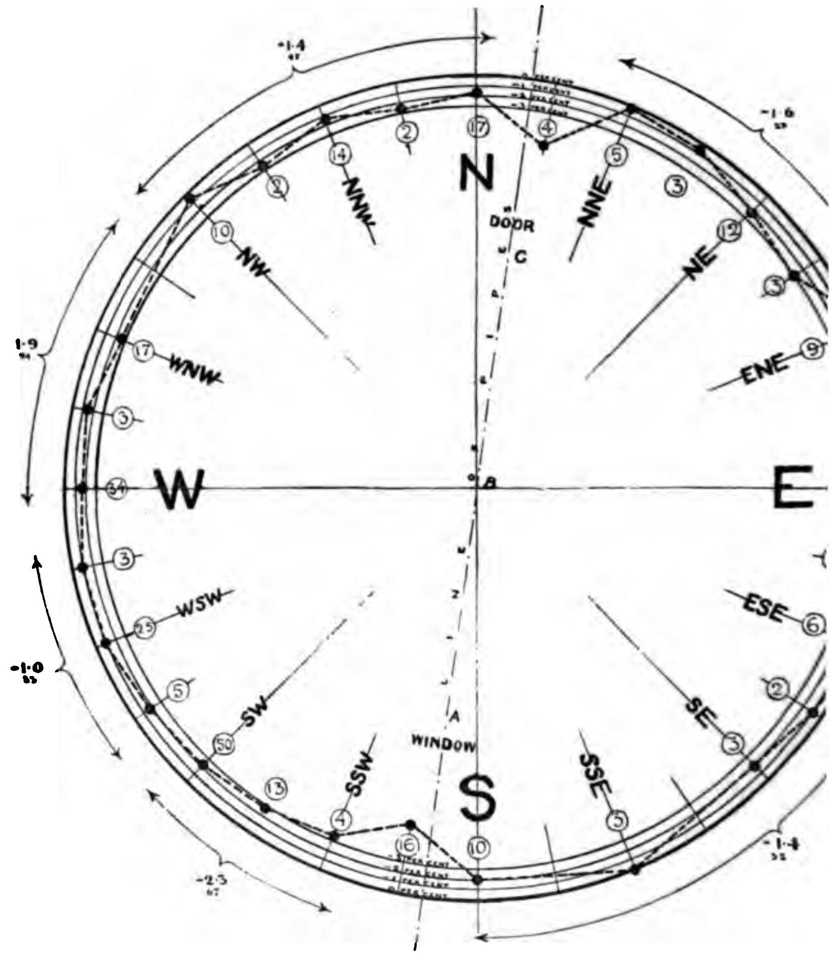
E.		E. by S.		E.S.E.	
Index No. of Experiment.	Difference per cent.	Index No. of Experiment.	Difference per cent.	Index No. of Experiment.	Difference per cent.
36	0	330	−2	460	0
37	0	331	−2	1008	−3
38	+1	334	−4	1383	+1
41	−2	336	−3	1384	+2
42	−2	338	−4	1397	+1
43	−1	340	−2	1474	0
44	−2	479	−2		
45	0	482	0		
46	+1				
47	+1				
176	0				
303	+4				
308	+6				
312	+7				
342	0				
343	0				
402	0				
408	+1				
411	+1				
1340	+3				
1341	+4				
1618	−1				
1951	−3				
23 Expmts.	+0·8 Mean	8 Expmts.	−2·4 Mean	6 Expmts.	+0·2 Mean

The average differences, both of the 3-in. and of the 6-in. o experiments were then plotted in compass form upon the f diagrams :—

3-inch Open Pipe Experiments; all three Pi

(Excluding Experiments in which the Upcast of **A** *and* **C** *diff more than 10 per cent.)*

Diagram showing difference per cent. between Upcast* of Pipe B sta that of mean of Pipes A and C, arranged according to direction of w



The outer circle represents the standard (Pipe B), and the inner circle repres of differences per cent. from the standard.

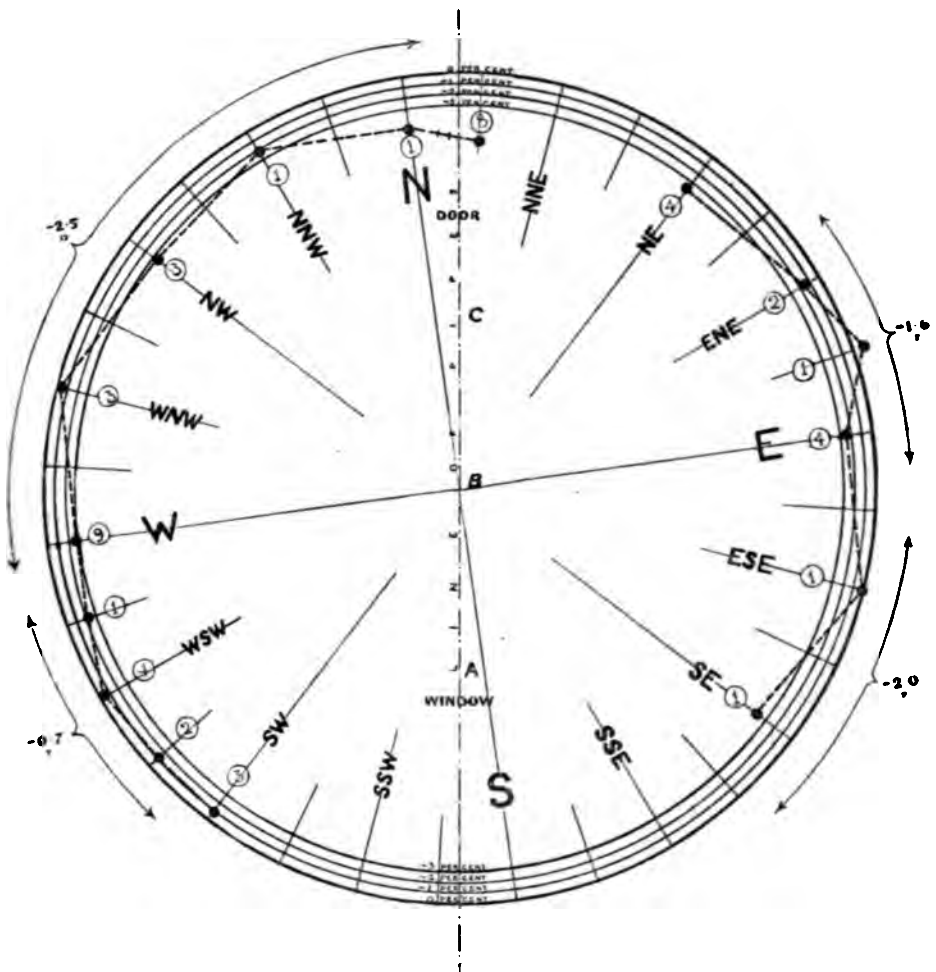
The full circle joined by dotted lines represent the actual average differen between B and mean of A and C. The figures in circles represent the number ments from which the averages are obtained. The figures outside the pointe shew the corrections adopted for that segment, and the small figures below rections give the number of observations included.

* Upcast velocity feet per minute (corrected)

Diagram 31.

6-inch Open Pipe Experiments.

(See Heading to Diagram 31).



(See Note, diagram 31).

Diagram 32.

The average percentage differences were found to vary so muc special investigation had to be made to ascertain the cause of tl tion. With this object the percentage ratios of upcast in the thı were calculated, taking Pipe B as 100, and entered in two three-piı Compass tables in which the ratios were arranged according to tb tion of the wind, with a subsidiary arrangement according to the or + of the percentage difference, as shown by the following extra the tables:—

1	18	19	20				22
	Pipe Three inches Internal Diameter.						
Index Number of Experiment.	Upcast Velocity (corrected).			Ratios.			Col. 19 di from Col per ce
	Pipe A	Pipe B	Pipe C	A	B	C	+
			W.	S.W.			
69	314	316	322	99	100	102	...
70	279	281	287	99	100	102	...
124	241	243	248	99	100	102	...
208	154	155	164	99	100	106	...
423	159	159	159	100	100	100	0
787	201	206	217	98	100	105	...
792	171	172	183	99	100	106	...
799	339	333	356	102	100	107	...
883	329	323	336	102	100	104	...
884	372	368	372	101	100	101	...
903	220	219	221	100	100	101	...
1060	288	297	311	97	100	105	...
1295	84	83	86	101	100	104	...
1351	140	144	151	97	100	105	...
1373	165	167	169	99	100	101	0
1402	291	296	317	98	100	107	...
1468	95	92	92	103	100	100	...
1507	253	258	263	98	100	102	0
1944	559	535	560	104	100	105	...
Means	...	...	...	99	100	103	
205	165	173	173	95	100	100	2
218	238	247	252	96	100	102	1
421	187	189	187	99	100	99	1
422	165	167	167	99	100	100	1
1372	190	196	196	97	100	100	2
1943	496	522	514	95	100	98	3
Means	...	...	...	97	100	100	

NOTE.—The Numbers at the head of each Column are taken from the Complete Tabulati which Col. 21 is the mean of Col. 18 and Col. 20.

Experiments in which the difference in the upcast between A exceeded 10 per cent. were rejected: the remaining ratios we entered at each point of the compass on the following Diagrams, and 307.

In order to obtain more reliable average differences and ratios from a larger number of experiments at each point of the compass, the results of the differences for the 3-in. and 6-in. pipes were combined in one table, and the ratios for the two sizes of pipes on another separate table. The system of this combination is indicated in the case of differences by the following example:—

		S.W. by W.	W.S.W.	W. by S.
Number of Experiments averaged:	3-in.	5	25	3
	6-in.	2	4	1
Total		7	29	4
Algebraical sum of differences per cent.: ...	3-in.	− 8	−22	−3
	6-in.	− 2	− 1	−2
Total (Algebraical) ...		−10	−23	−5
Average of differences per cent., 3-in. & 6-in. combined		− 1·4	−0·8	−1·3

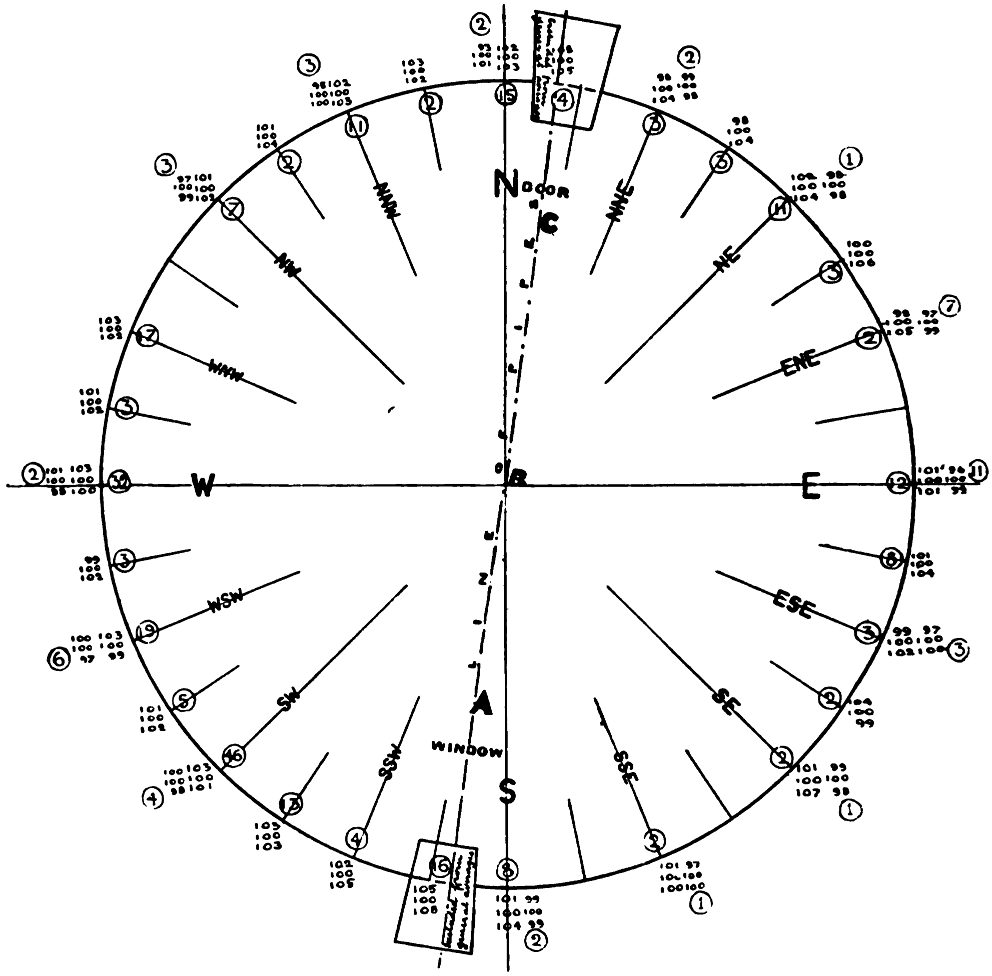
The averages of the combined 3-in. and 6-in experiments, both in the case of differences and of ratios per cent., were then plotted on the following Diagrams, 308 and 309, in compass form.

A similar method of combining the 3-in. and 6-in. experiments was adopted in the case of the ratios, as shown in the extract, given on p. 310, from the corresponding three-pipe Ratio Compass Table, in which Pipe B was taken throughout as 100.

3-inch Open Pipe Experiments; all three Pipes.

(Excluding Experiments in which the Upcast of A *and* C *differs by more than 10 per cent.)*

Diagram showing Ratios of Upcast of Pipes A, B, and C, arranged according to direction of wind (see Note below as to subsidiary arrangements).



The Upcast of Pipe B is taken as 100, and the figures written below and written above the 100 represent the Upcasts of Pipes A and C respectively, thus:—

{103 C Pipe. 100 B Pipe.} 101 A Pipe.

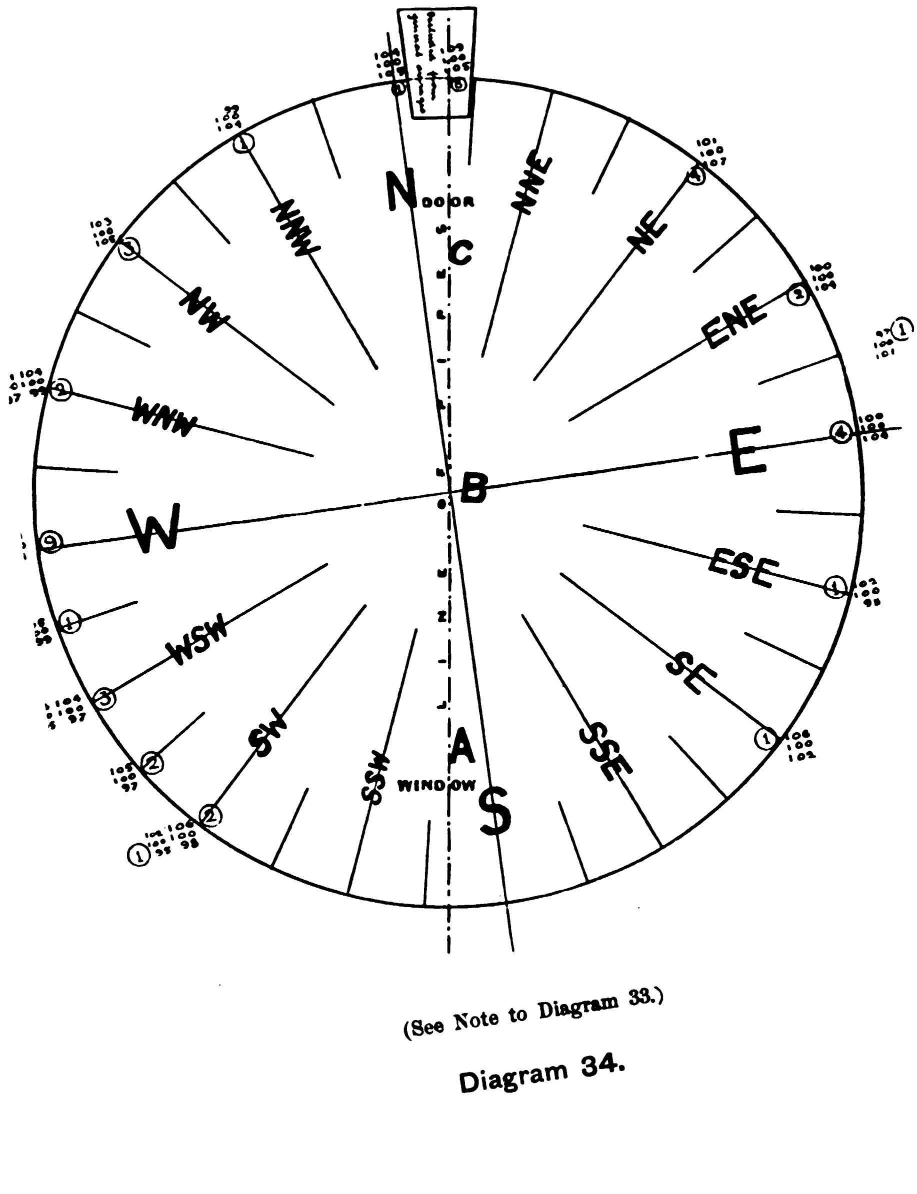
Subsidiary Arrangements.—The groups of figures nearest the numerals in the circles inside the compass ring show Ratios of Experiments which have a minus percentage difference in Cols. 22–23 of complete tabulation, *i.e.*, those in which the Upcast in the centre pipe is less than the mean of the two outside pipes.

The additional groups of figures nearest to the numerals in small circles outside the compass ring show Ratios of Experiments which have a plus percentage difference in Cols. 22–23 of complete tabulation, *i.e.*, those in which the Upcast in the central pipe exceeds the mean of the outside pipes.

Diagram 33.

6-inch Open Pipe Experiments.

(See Heading to Diagram 33.)



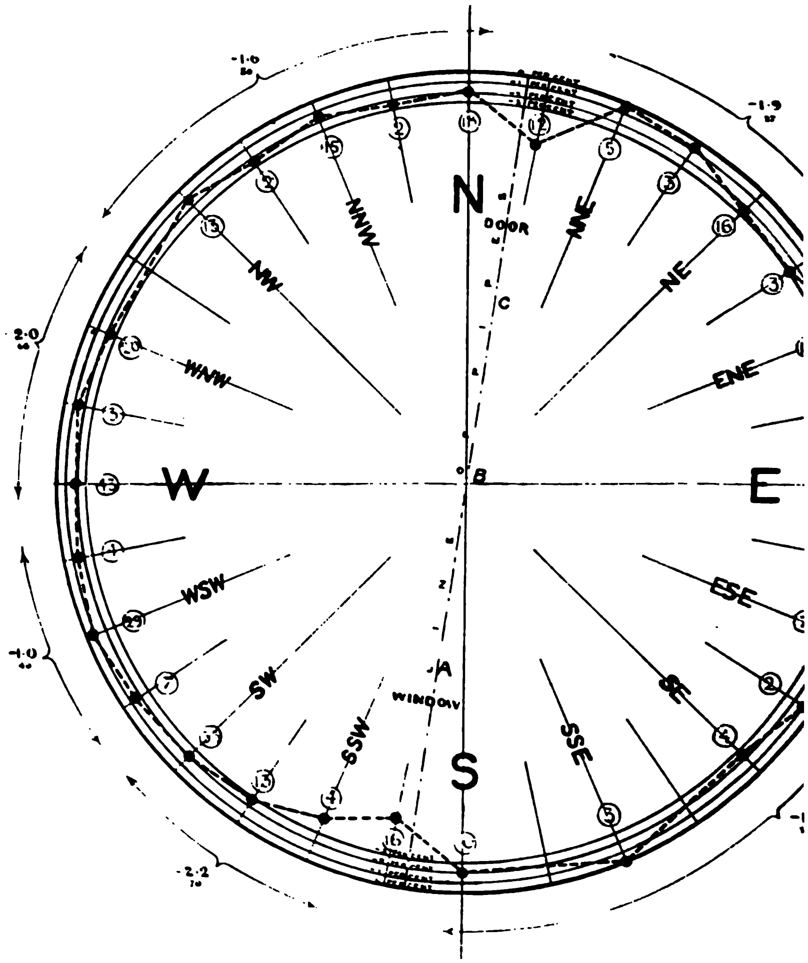
(See Note to Diagram 33.)

Diagram 34.

3-inch and 6-inch Open Pipe Experiment

Differences.

(See Heading, Diagram 31).



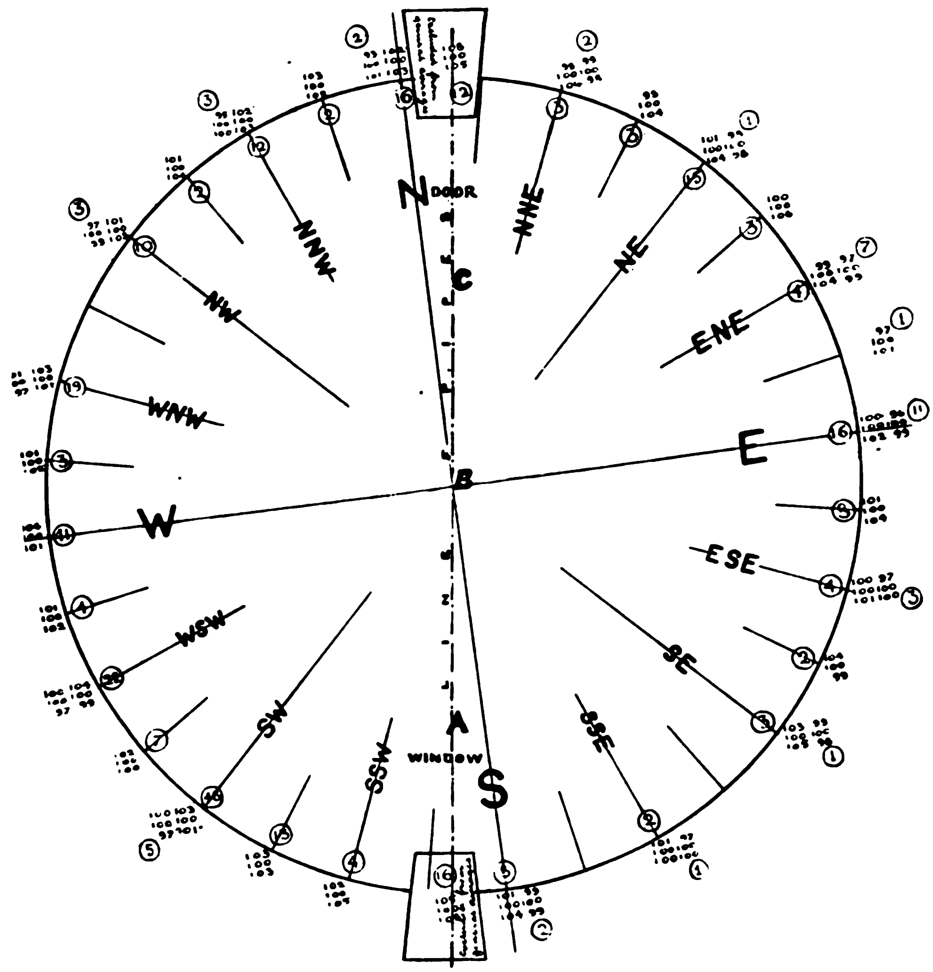
(See Foot Note, Diagram 31, p. 302).

Diagram 35.

3-inch and 6-inch Open Pipe Experiments.

Ratios.

(See Heading to Diagram 33.)



(See Note to Diagram 33, p. 306.)

Diagram 36.

		W.		W. by N.		W.
		Pipe A	Pipe C	Pipe A	Pipe C	Pipe A
Number of Experiments averaged:						
Number of Minus Experiments ...	3-in.	32		3		
	6-in.	9				
Total		41		3		-
Number of Plus Experiments ...	3-in.	2				-
	6-in.					
Total		2				-
Totals of Ratios:						
Minus Experiments (Totals) ...	3-in.	3209	3307	305	302	1728
	6-in.	912	937			197
Total		4121	4244	305	302	1925
Plus Experiments (Totals)	3-in.	195	201			
	6-in.					97
Total		195	201			97
Averages of Ratios, 3-in. & 6-in. combined:						
Minus Experiments		101	104	102	101	101
Plus Experiments		98	101			97
(Total number)		(4	3)	(	3)	(
General Average (taken from Totals) + & − combined		100	103	102	101	101

A separate investigation was next made into the cause of the p
percentage differences. For this purpose two special summaries
periments with 3-in. pipes were prepared, showing the ratios of up
the three Pipes A, B, and C, taking B as 100. In one of these sum
experiments with both negative and positive percentage difference
included, and the ratios were arranged according to the direction o
and secondly according to the sign and magnitude of the perc
differences, somewhat similarly to the ratio table shown on page 304

In the other summary only experiments with the positive perc
differences were included, and these were arranged according
magnitude of the percentage differences irrespective of the direct
wind. A synopsis of this table is given in following table.

Centre Pipe differs from Mean of Outside Pipes per cent.	No. of Experiments.	E. side of Compass N.W. through E. to S.E. Ratios.			No. of Experiments.	W. side of Compass, N.W. by W., through W. to S.E. by S. Ratios.		
		A	B	C		A	B	C
+1	16	100	100	98	10	98	100	100
+2	8	100	100	96	6	95	100	102
+3	4	99	100	95	1	95	100	98
+4	7	101	100	91				
+6	5	100	100	89				
+7	3	98	100	89				
+8	2	98	100	87				

On carefully examining these results and comparing the ratios of the upcast velocity in the two outside open Pipes A and C for different points of the compass, there was no striking difference between the ratios in the case of experiments which give the positive percentage differences for the mean of A and C against B and those in the case of the negative percentages; the consideration of the ratios of the upcast velocity in the two outside pipes accordingly threw no light on the cause of the positive percentages. The ratios of the two outside pipes did not however appear to follow any regular rule, and it was clear that the experiments dealt with in the investigation were for most points of the compass too few in number for any reliable conclusion to be drawn from them.

In order to throw additional light upon the relation of the upcast in the pipes, it was decided to make use of the experiments in which only two open pipes were used (the centre pipe having a Cowl or Terminal on it).

In order to distinguish the two different kinds of open pipe experiments, the following nomenclature was adopted: The experiments upon three open pipes (no Cowl or Terminal on centre pipe) were termed "Special" Open Pipe experiments, as they were tried specially to obtain results for Open Pipes. The experiments upon two open pipes (where the centre pipe had a Cowl or Terminal on it) were termed "Incidental" Open Pipe experiments, as they only incidentally yielded results for Open Pipes, their primary object being to obtain results for Cowls and Terminals. The total number of "Special" and "Incidental" Open Pipe experiments used in the preparation of the comparison of upcasts in the two outside pipes was nearly 4,000.

To obtain the ratios of the upcast velocity in the two outside pipes from the "Incidental" Open Pipe experiments, a different standard had to be taken from that used in the three-pipe Ratio Compass Tables.

In the Ratio Compass Tables the upcast velocity in the centre pipe was taken as the standard, but this standard could not be adopted in the "Incidental" Open Pipe experiments, as the centre pipe was not a plain open pipe, but had a Cowl or Terminal on it. As what was required in the "Incidental" Open Pipe experiments was the ratio of the upcast velocity in one outside pipe to that in the other, Pipe A, which came first in other tabulations, was for convenience selected, and the upcast velocity in it taken as 100.

The results of the early "Incidental" experiments were entered in a table in which the ratios of upcast in Pipes A and C, taking A = 100, were arranged according to direction of wind. The upcast results were obtained from the Complete Tabulation (see p. 396) and the ratios calculated. As a specimen of the construction of this table, the following single wind direction W. by S. has been selected:—

Roman Figure on Complete Tabulation.	Index Number of Experiment.	Pipe 3-in. Internal Diameter.		
		Upcast Velocity, feet per minute.		Percentage Ratio.
		Pipe A	Pipe C	Pipe C / Pipe A
12	98	143	143	100
13	2002	207	196	95
13	2003	262	249	95
15	1998	275	262	95
15	1999	220	208	95
15	2001	201	192	96
16	419	246	240	98
21	235	186	202	109
21	236	214	234	109
22	237	208	222	107
22	238	201	220	109
24	1176	215	222	103
25	240	204	221	108
43	1297	283	297	105
		14 Experiments ...		102

These diagrams showed very remarkable results as regards the ratio of upcast velocity in the two outside pipes:

(1) The early "Incidental" Open Pipe experiments agreed substantially with the later ones.

(2) The variations in the ratios were fairly regular.

(3) The variations were greatest with directions of wind which

prima facie would not have been considered likely to give large variations in the relative upcast of the two outside pipes.

As the results (1) and (2) showed that the ratios of upcast velocity in the two outside open pipes in the case of the "Incidental" Open Pipe experiments were quite reliable, the Committee considered it desirable to ascertain whether the same variations would obtain in the "Special" open pipe experiments. The "Special" Open Pipes were therefore similarly treated (see Diagrams 37 and 38), and the whole of the results of the early and later "Special" and "Incidental" Open Pipe experiments were entered in the following "Summary Table of Ratios of Upcast in Two Outside Open Pipes, A being taken as 100" (see Tables XIX. to XXV). All the Special Experiments were then plotted on Diagram 39, and all the Incidental Experiments on Diagram 42, and then the complete results combined on Diagram 43.

Table XIX.—Ratios of Upcast in Two Outside Open Pipes.

Calculated from EARLY SPECIAL *Experiments (previous to March, 1894) on a Three Open Pipes.*

3-inch.

NOTE.—The Totals of Ratios in Cols. 3 and 4 are obtained from the figures for 3-in. Pipes in "Open Pipes, Special Experiments, all three pipes, Early Experime by adding the totals of 3-in. Ratios for + and − Experiments (ignoring sign).

The results in Cols. 5 and 6 are calculated from Cols. 3 and 4 by taking Col. 3 as 1(

1	2	3	4	5	6	1	2	3	4	5
Wind Direction.	No. of Experiments.	Totals of Ratios, taking Pipe B as 100. (See note above.)		Average Ratios of Outside Pipes. (See note above.)		Wind Direction.	No. of Experiments.	Totals of Ratios, taking Pipe B as 100. (See note above.)		Averag Ratios Outside P (See no above
		A	C	A	C			A	C	A
N.	17	1742	1712	100	98	S.	10	1032	1003	100
N. by E.	4	421	430	100	102	S. by W.	16	1728	1686	100
Line of Pipes N.N.E.	5	509	491	100	96	Line of Pipes S.S.W.	4	418	407	100
N.E. by N.	3	312	293	100	94	S.W. by S.	13	1335	1337	100
N.E.	12	1238	1214	100	98	S.W.	50	5053	5157	100
N.E. by E.	3	317	301	100	95	S.W. by W.	5	508	507	100
E.N.E.	9	904	875	100	97	W.S.W.	25	2476	2564	100
E. by N.	...	...	...	...	...	W. by S.	3	307	297	100
E.	23	2305	2258	100	98	W.	34	3404	3508	100
E. by S.	8	830	808	100	97	W. by N.	3	305	302	100
E.S.E.	6	606	590	100	97	W.N.W.	17	1728	1756	100
S.E. by E.	2	198	207	100	105	N.W. by W.	...	...	...	...
S.E.	3	312	301	100	96	N.W.	10	1013	997	100
S.E. by S.	...	...	...	...	...	N.W. by N.	2	207	201	100
S.S.E.	3	300	298	100	99	N.N.W.	14	1430	1405	100
S. by E.	...	...	...	...	...	N. by W.	2	204	205	100

To Illustrate Table XIX.

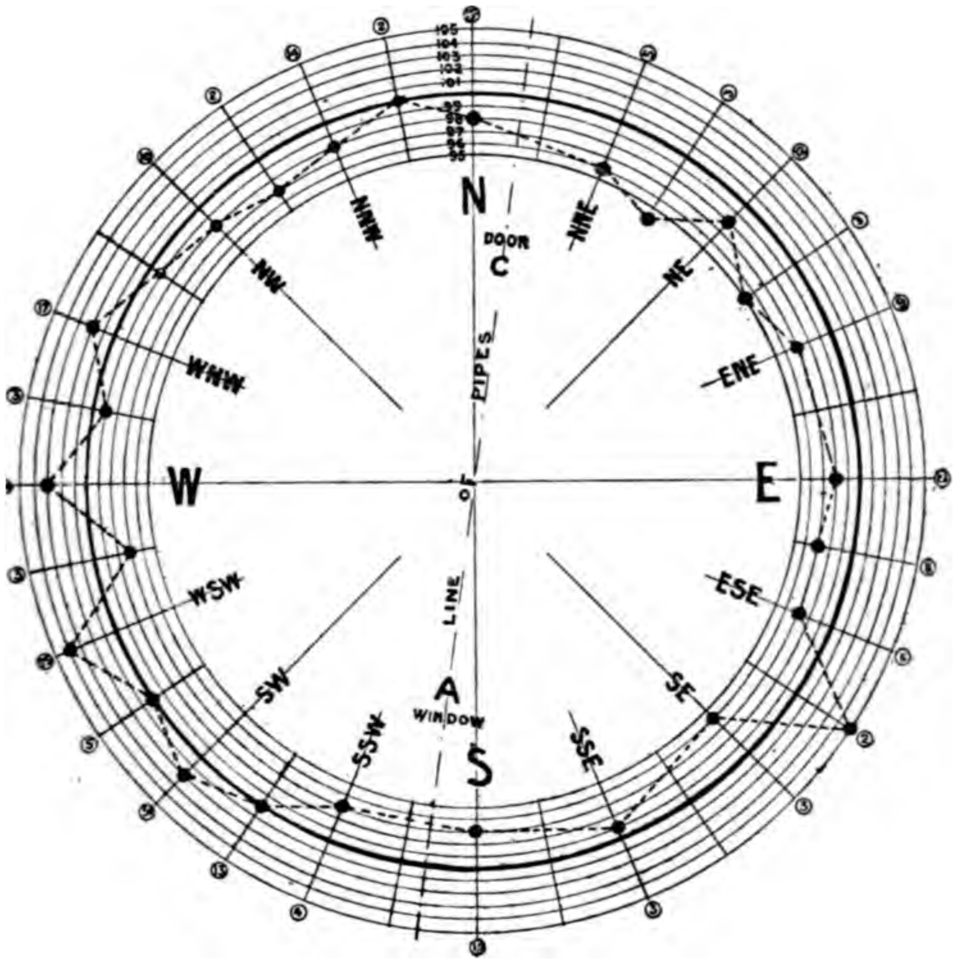


Diagram 37.

Table XX.—Ratio of Upcast in Two Outside Open Pipes.

Calculated from Later Special *Experiments (to 16th August, 1897 only), all Three Open Pipes.*

3-inch.

Note.—The figures in Cols. 2, 3, and 4 are taken from the red figures in "Open I Special Experiments, all three Pipes, Later Experiments."

The results in Cols. 5 and 6 are calculated from Cols. 3 and 4 by taking Col. 3 as

1	2	3	4	5	6	1	2	3	4	5
Wind Direction.	No. of Experiments.	Totals of Ratios, taking Pipe B as 100. (See note above.)		Average Ratios of Outside Pipes. (See note above.)		Wind Direction.	No. of Experiments.	Totals of Ratios, taking Pipe B as 100. (See note above.		Avera Ratios Outside I (See r abov
		A	C	A	C			A	C	A
N.	7	723	708	100	98	S.	1	106	106	100
N. by E.	...	...	...	...	...	S. by W.	...	...	...	...
Line of Pipes.						Line of Pipes.				
N.N.E.	6	618	615	100	100	S.S.W.	...	...	...	...
N.E. by N.	10	1042	1005	100	96	S.W. by S.	13	1301	1339	100
N.E.	12	1253	1196	100	95	S.W.	19	1888	1978	100
N.E. by E.	5	521	496	100	95	S.W. by W.	19	1880	1941	100
E.N.E.	7	716	683	100	95	W.S.W.	19	1873	1937	100
E. by N.	6	617	604	100	98	W. by S.	28	2758	2821	100
E.	14	1439	1392	100	97	W.	18	1809	1845	100
E. by S.	13	1339	1326	100	99	W. by N.	10	998	985	100
E.S.E.	5	500	501	100	100	W.N.W.	13	1336	1297	100
S.E. by E.	4	398	404	100	102	N.W. by W.	11	1129	1102	100
S.E.	5	512	512	100	100	N.W.	11	1132	1069	100
S.E. by S.	1	105	105	100	100	N.W. by N.	7	730	698	100
S.S.E.	5	506	513	100	101	N.N.W.	7	723	694	100
S. by E.	2	208	209	100	100	N. by W.	8	826	807	100

To Illustrate Table XX.

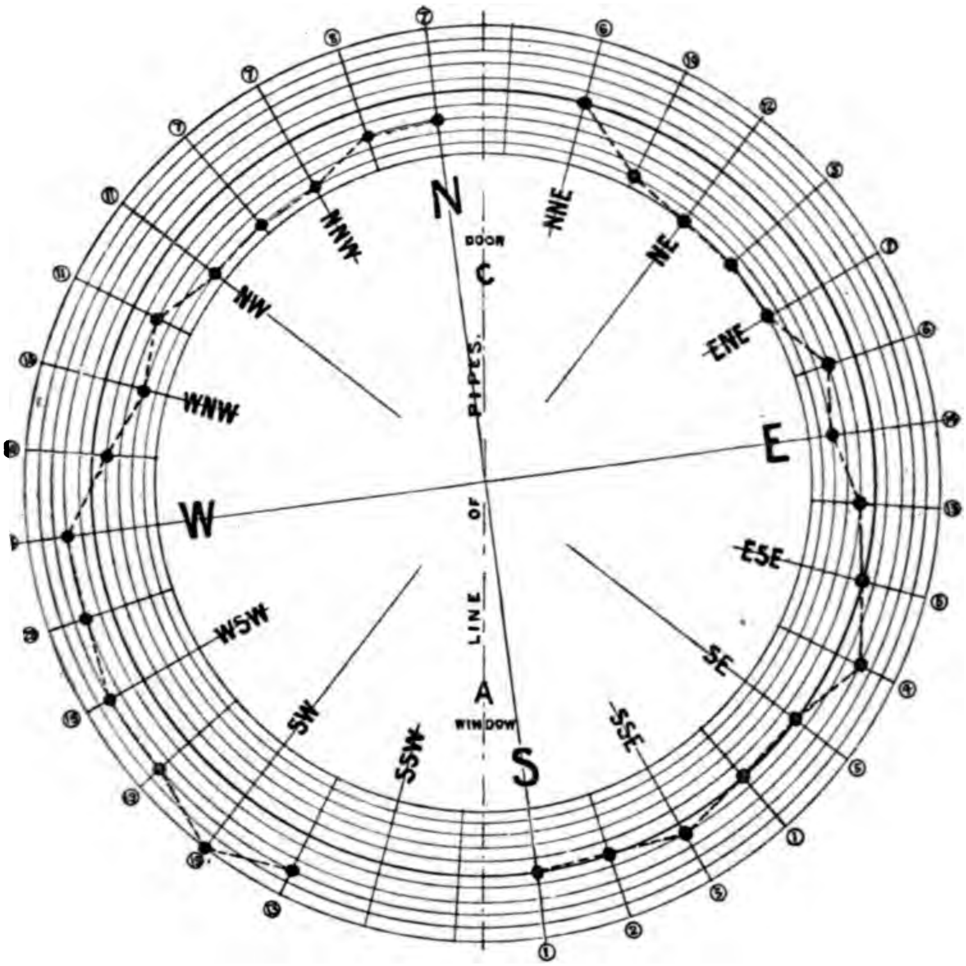


Diagram 38.

Table XXI.—Ratios of Upcast in Two Outside Open Pipes, A being taken as 100.

Calculated from Both Early and Later Special *Experiments* *(to 16th August, 1897, only).*

3-inch.

Note.—The results in Col. 7 are calculated thus: $\text{Col. } 7 = \frac{(\text{Col. } 2 \times \text{Col. } 3) + (\text{Col. } 4 \times \text{Co}}{\text{Col. } 2 + \text{Col. } 4.}$

1	2	3	4	5	6	7	1	2	3	4	5	6
	Early.		Later.		All special. (See note above.)			Early.		Later.		All spe (See n abov
Wind Direction.	No. of Experiments.	Ratio of C to A.	No. of Experiments.	Ratio of C to A.	No. of Experiments.	Ratio of C to A.	Wind Direction.	No. of Experiments.	Ratio of C to A.	No. of Experiments.	Ratio of C to A.	No. of Experiments.
N.	17	98	7	98	24	98	S.	10	97	1	100	11
N.N.E.	5	96	6	100	11	98	S.S.W.	4	97	...	...	4
N.E. by N.	3	94	10	96	13	96	S.W. by S.	13	100	13	103	26
N.E.	12	98	12	95	24	97	S.W.	50	102	19	105	69
N.E. by E.	3	95	5	95	8	95	S.W. by W.	5	100	19	103	24
E.N.E.	9	97	7	95	16	96	W.S.W.	25	104	19	103	44
E. by N.	...	...	6	98	6	98	W. by S.	3	97	28	102	31
E.	23	98	14	97	37	98	W.	34	103	18	102	52
E. by S.	8	97	13	99	21	98	W. by N.	3	99	10	99	13
E.S.E.	6	97	5	100	11	98	W.N.W.	17	102	13	97	30
S.E. by E.	2	105	4	102	6	103	N.W. by W.	...	...	11	98	11
S.E.	3	96	5	100	8	99	N.W.	10	98	11	96	21
S.E. by S.	...	...	1	100	1	100	N.W. by N.	2	97	7	96	9
S.S.E.	3	99	5	101	8	100	N.N.W.	14	98	7	96	21
S. by E.	...	...	2	100	2	100	N. by W.	2	100	8	98	10

To Illustrate Table XXI.

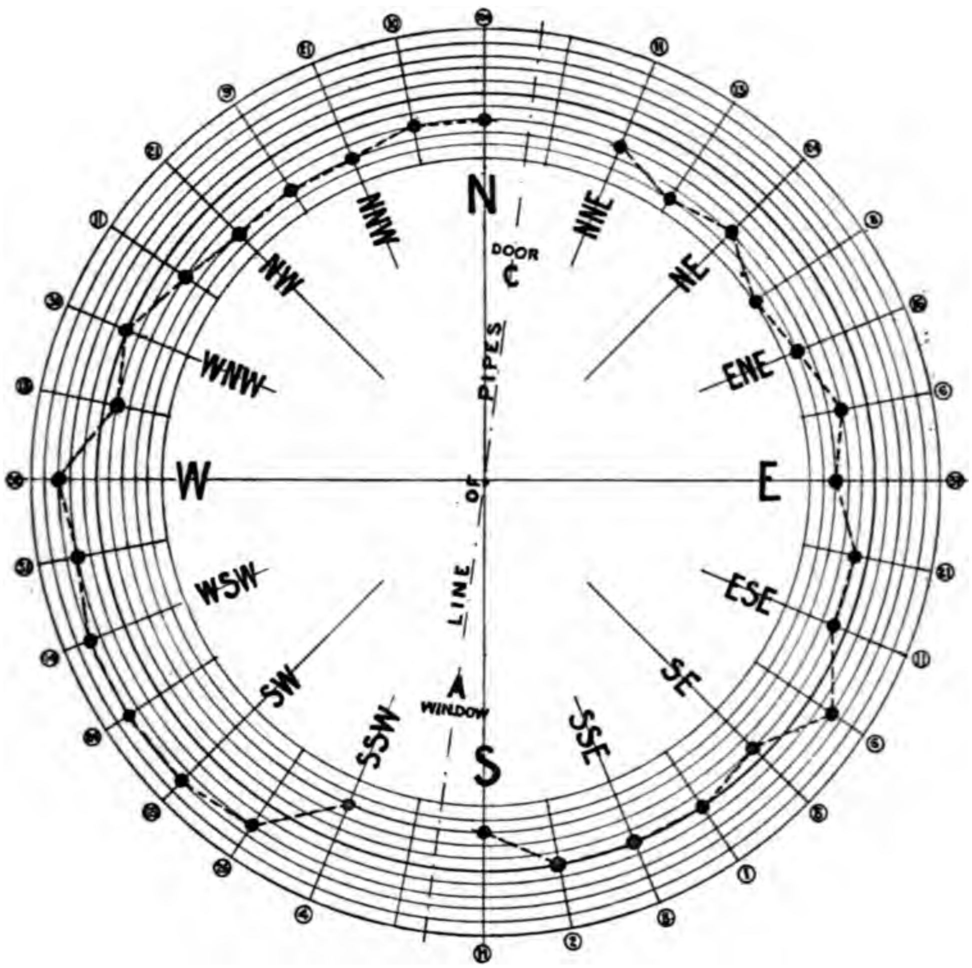


Diagram 39.

Table XXII.—Ratios of Upcast in Two Outside Open Pipes.

Calculated from Early Incidental *Experiments (previous to March, 1894), on Two Outside Pipes only.*

3-inch.

Note.—The figures in Cols. 2, 3 and 4 are taken from the red figures in "Open Pipes, Incidental Experiments, Two Outside Pipes only. Early Experiments."

1	2	3	4	1	2	3	
Wind Direction.	No. of Experiments.	Average of Ratios.		Wind Direction.	No. of Experiments.	Average of Ratios.	
		A	C			A	C
N.	53	100	100	S.	11	100	96
N. by E.	...	...	...	S. by W.	...	...	...
Line of Pipes.				Line of Pipes.			
N.N.E.	4	100	97	S.S.W.	6	100	93
N.E. by N.	9	100	98	S.W. by S.	12	100	99
N.E.	47	100	97	S.W.	68	100	104
N.E. by E.	...	...	...	S.W. by W.	9	100	103
E.N.E.	45	100	97	W.S.W.	96	100	104
E. by N.	1	100	96	W. by S.	14	100	102
E.	70	100	96	W.	149	100	104
E. by S.	13	100	96	W. by N.	10	100	102
E.S.E.	10	100	100	W.N.W.	64	100	102
S.E. by E.	...	...	...	N.W. by W.	2	[illegible]	97
S.E.	11	100	99	N.W.	33	[illegible]	98
S.E. by S.	...	...	...	N.W. by N.	3	100	100
S.S.E.	6	100	99	N.N.W.	44	100	97
S. by E.	...	...	...	N. by W.	7	100	[illegible]

To Illustrate Table XXII.

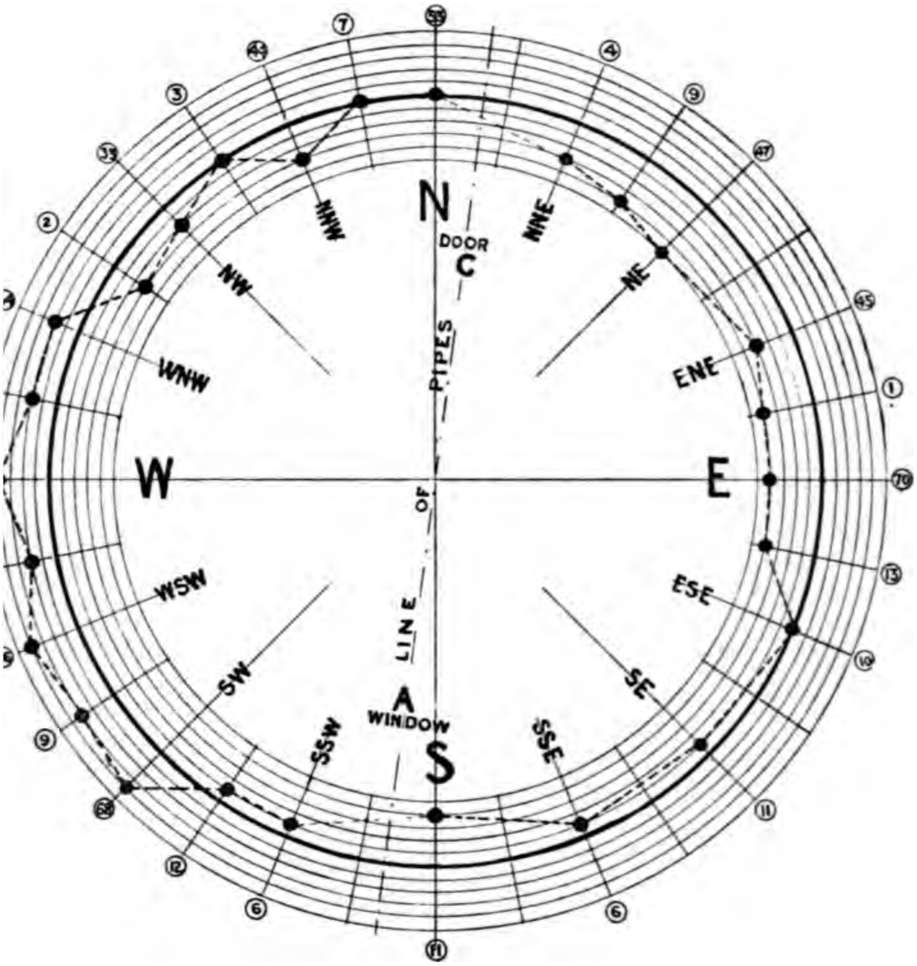


Diagram 40.

Table XXIII.—Ratios of Upcast in Two Outside Open Pipes.

Calculated from Later Incidental *Experiments (to 16th August, 1897, only) on Two Outside Pipes.*

3-inch.

Note.—The figures in Cols. 2, 3 and 4 are taken from the red figures in "Open Pipes, Incidental Experiments, Two Outside Pipes only. Later Experiments."

1	2	3	4	1	2	3	4
Wind Direction.	No. of Experiments.	Average of Ratios.		Wind Direction.	No. of Experiments.	Average of Ratios.	
		A	C			A	C
N.	11	100	99	S.	7	100	99
N. by E. Line of Pipes.	...	...	...	S. by W. Line of Pipes.	...	...	...
N.N.E.	30	100	101	S.S.W.	27	100	101
N.E. by N.	52	100	97	S.W. by S.	164	100	103
N.E.	60	100	96	S.W.	201	100	106
N.E. by E.	28	100	95	S.W. by W.	174	100	105
E.N.E.	47	100	95	W.S.W.	166	100	104
E. by N.	79	100	97	W. by S.	203	100	102
E.	123	100	98	W.	224	100	102
E. by S.	125	100	99	W. by N.	158	100	100
E.S.E.	51	100	99	W.N.W.	129	100	99
S.E. by E.	25	100	100	N.W. by W.	120	100	97
S.E.	21	100	101	N.W.	118	100	97
S.E. by S.	15	100	100	N.W. by N.	68	100	96
S.S.E.	20	100	101	N.N.W.	55	100	97
S. by E.	8	100	101	N by W.	26	100	98

To Illustrate Table XXIII.

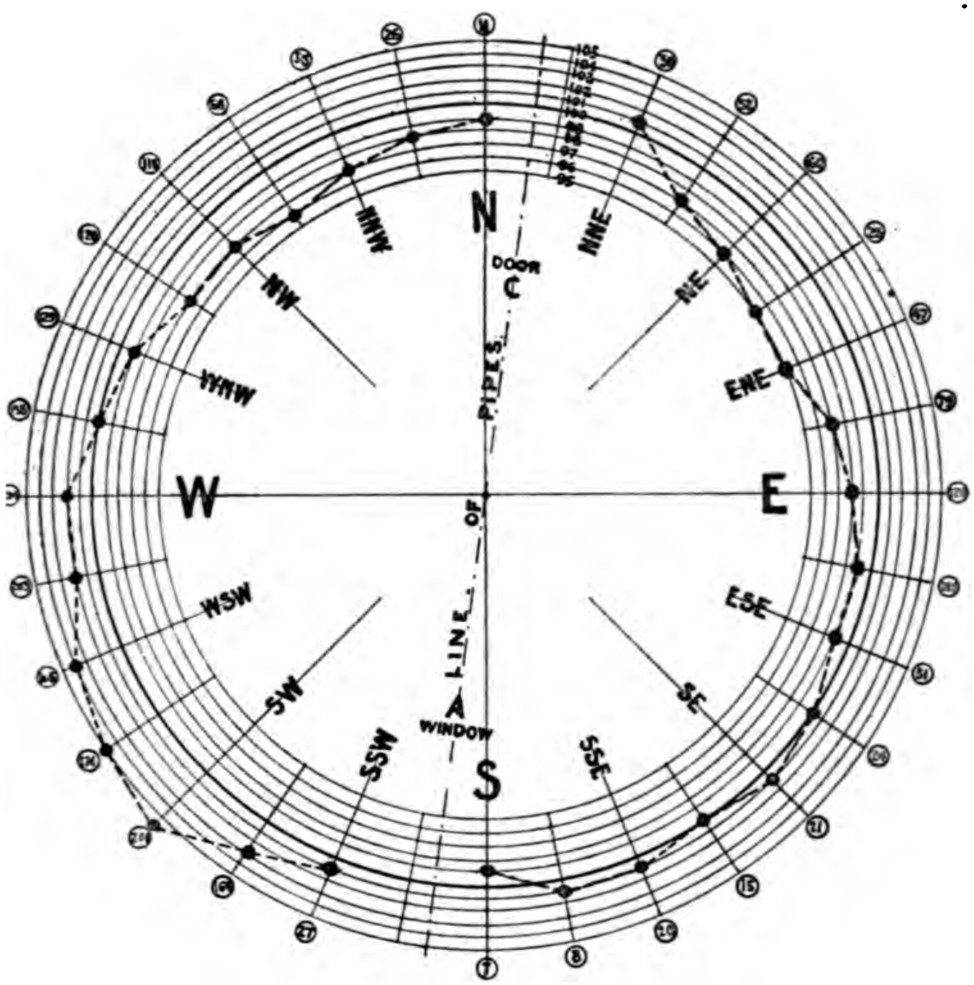


Diagram 41.

Table XXIV.—Ratios of Upcast in Two Outside Open Pipes. A being taken as 100.

Calculated from BOTH EARLY AND LATER INCIDENTAL *Experiments to 16th August, 1897, only.*

3-inch.

NOTE.—The results in Col. 7 are calculated thus: $\text{Col. }7=\frac{(\text{Col. }2\times\text{Col. }3)+(\text{Col. }4\times\text{Col. }5.)}{\text{Col. }2+\text{Col. }4.}$

1	2	3	4	5	6	7	1	2	3	4	5	6	7
Wind Direction	Early.		Later.		All Incidental. (See note above.)		Wind Direction.	Early.		Later.		All Incidental. (See note above.)	
	No. of Experiments.	Ratio of C to A.	No. of Experiments.	Ratio of C to A.	No. of Experiments.	Ratio of C to A.		No. of Experiments.	Ratio of C to A.	No. of Experiments.	Ratio of C to A.	No. of Experiments.	Ratio of C to A.
N.	53	100	11	99	64	100	S.	11	96	7	99	18	97
N.N.E.	4	97	30	101	34	101	S.S.W.	6	99	27	101	33	101
N.E. by N.	9	96	52	97	61	97	S.W. by S.	12	99	164	103	176	103
N.E.	47	97	60	96	107	96	S.W.	68	104	201	106	269	105
N.E. by E.	...	...	28	95	28	95	S.W. by W.	9	103	174	105	183	105
E.N.E.	45	97	47	95	92	96	W.S.W.	96	104	166	104	262	104
E by N.	1	96	79	97	80	97	W. by S.	14	102	203	102	217	102
E.	70	96	123	98	193	97	W.	149	104	224	102	373	103
E. by S.	13	96	125	99	138	99	W. by N.	10	102	158	100	168	100
E.S.E.	10	100	51	99	61	99	W.N.W.	64	102	129	99	193	100
S.E. by E.	...	...	25	100	25	100	N.W. by W.	2	97	120	97	122	97
S.E.	11	99	21	101	32	100	N.W.	33	98	118	97	151	97
S.E. by S.	...	...	15	100	15	100	N.W. by N.	3	100	68	96	71	96
S.S.E.	6	99	20	101	26	101	N.N.W.	44	97	55	97	99	97
S. by E.	...	...	8	101	8	101	N. by W.	7	100	26	98	33	98

To Illustrate Table XXIV.

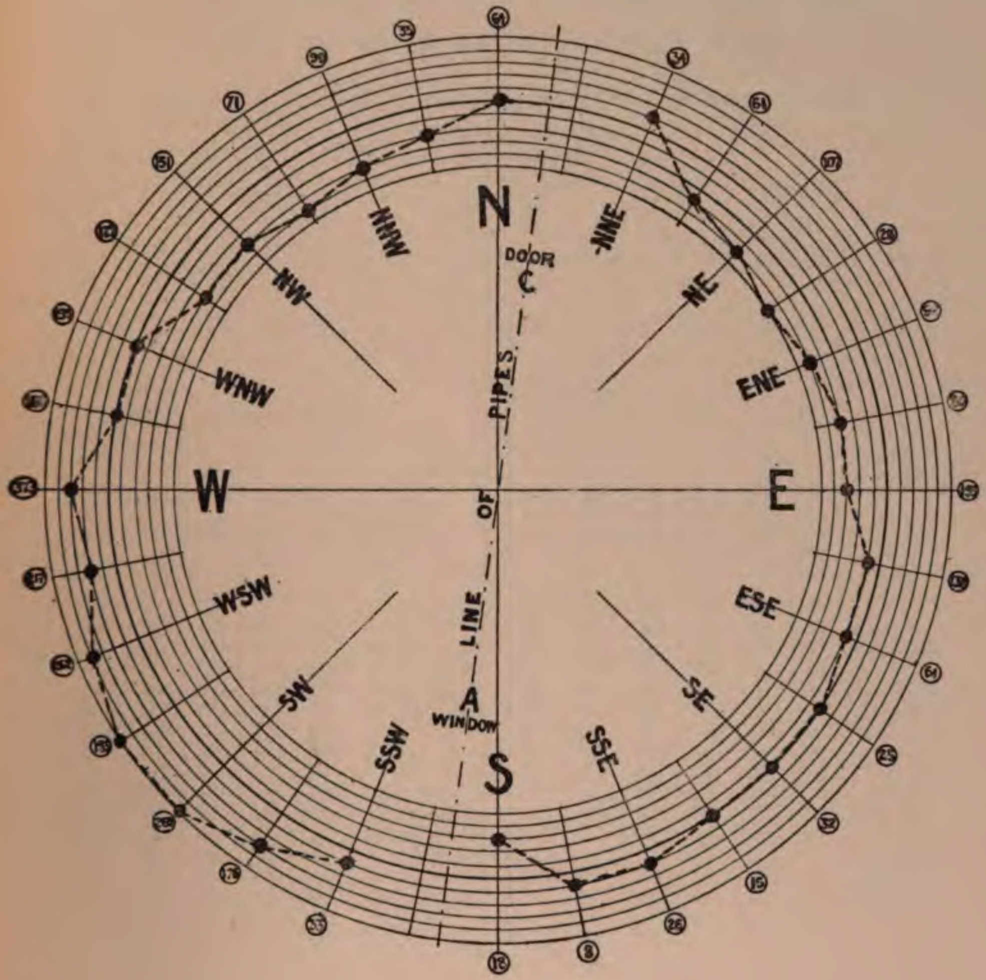


Diagram 42.

Table XXIV.—Ratios of Upcast in Two Outside Open Pipes. A being taken as 100.

Calculated from BOTH EARLY AND LATER INCIDENTAL *Experiments to 16th August, 1897, only.*

3-inch.

NOTE.—The results in Col. 7 are calculated thus: Col. $7 = \frac{(\text{Col. } 2 \times \text{Col. } 3) + (\text{Col. } 4 \times \text{C}}{\text{Col. } 2 + \text{Col. } 4.}$

1	2	3	4	5	6	7	1	2	3	4	5	6
	Early.		Later.		All Incidental. (See note above.)			Early.		Later.		Al Incide (See abo
Wind Direction	No. of Experiments.	Ratio of C to A.	No. of Experiments.	Ratio of C to A.	No. of Experiments.	Ratio of C to A.	Wind Direction.	No. of Experiments.	Ratio of C to A.	No. of Experiments.	Ratio of C to A.	No. of Experiments.
N.	53	100	11	99	64	100	S.	11	96	7	99	18
N.N.E.	4	97	30	101	34	101	S.S.W.	6	99	27	101	33
N.E. by N.	9	96	52	97	61	97	S.W. by S.	12	99	164	103	176
N.E.	47	97	60	96	107	96	S.W.	68	104	201	106	269
N.E. by E.	...	...	28	95	28	95	S.W. by W.	9	103	174	105	183
E.N.E.	45	97	47	95	92	96	W.S.W.	96	104	166	104	262
E by N.	1	96	79	97	80	97	W. by S.	14	102	203	102	217
E.	70	96	123	98	193	97	W.	149	104	224	102	373
E. by S.	13	96	125	99	138	99	W. by N.	10	102	158	100	168
E.S.E.	10	100	51	99	61	99	W.N.W.	64	102	129	99	193
S.E. by E.	...	...	25	100	25	100	N.W. by W.	2	97	120	97	122
S.E.	11	99	21	101	32	100	N.W.	33	98	118	97	151
S.E. by S.	...	...	15	100	15	100	N.W. by N.	3	100	68	96	71
S.S.E.	6	99	20	101	26	101	N.N.W.	44	97	55	97	99
S. by E.	...	...	8	101	8	101	N. by W.	7	100	26	98	33

To Illustrate Table XXIV.

Diagram 42.

Table XXV.—Ratios of Upcast in Two Outside Open Pipes. A being taken as 100.

General Summary of Both Special and Incidental *Experiments (to 16th August, 1897, only).*

3-inch.

Note.—The results in Col. 7 are calculated thus: $\text{Col. }7 = \frac{(\text{Col. }2\times\text{Col. }3)+(\text{Col. }4\times\text{Col. }5)}{\text{Col. }2+\text{Col. }4}$.

1	2	3	4	5	6	7	1	2	3	4	5	6	7
Wind Direction.	All special.		All incidental.		All special and incidental combined. (See note above.)		Wind Direction.	All special.		All incidental.		All special and incidental combined. (See note above.)	
	No. of Experiments.	Ratio of C to A.	No. of Experiments.	Ratio of C to A.	No. of Experiments.	Ratio of C to A.		No. of Experiments.	Ratio of C to A.	No. of Experiments.	Ratio of C to A.	No. of Experiments.	Ratio of C to A.
N.	24	98	64	100	88	99	S.	11	97	18	97	29	97
N.N.E.	11	98	34	101	45	100	S.S.W.	4	97	33	101	37	101
N.E. by N.	13	96	61	97	74	97	S.W. by S.	26	102	176	103	202	103
N.E.	24	97	107	96	131	96	S.W.	69	103	269	105	338	105
N.E. by E.	8	95	28	95	36	95	S.W. by W.	24	102	183	105	207	105
E.N.E.	16	96	92	96	108	96	W.S.W.	44	104	262	104	306	104
E. by N.	6	98	80	97	86	97	W. by S.	31	102	217	102	248	102
E.	37	98	193	97	230	97	W.	52	103	373	103	425	103
E. by S.	21	98	138	99	159	99	W. by N.	13	99	168	100	181	100
E.S.E.	11	98	61	99	72	99	W.N.W.	30	100	193	100	223	100
S.E. by E.	6	103	25	100	31	101	N.W. by W.	11	98	122	97	133	97
S.E.	8	99	32	100	40	100	N.W.	21	97	151	97	172	97
S.E. by S.	1	100	15	100	16	100	N.W. by N.	9	96	71	96	80	96
S.S.E.	8	100	26	101	34	101	N.N.W.	21	97	99	97	120	97
S. by E.	2	100	8	101	10	101	N. by W.	10	98	33	98	43	98

To Illustrate Table XXV.

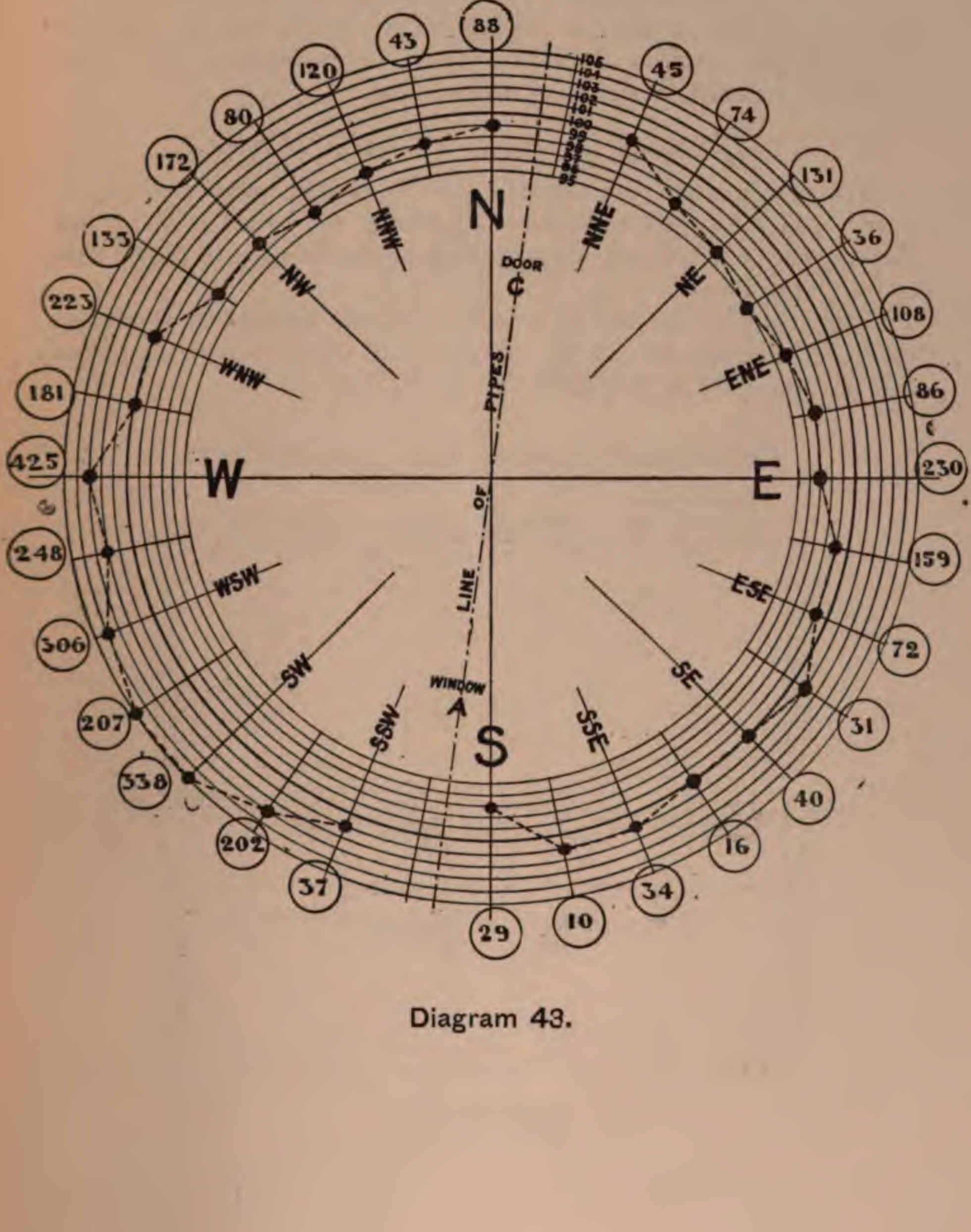


Diagram 43.

Finally, as the result of the above comprehensive work, the Committee decided that a fair standard with which to compare the upcast velocity in the cowl or terminal tested could be obtained from the mean of the upcast velocities in the two outer pipes if a small percentage correction were applied to this mean. This correction was generally minus two per cent., but for W. by S., W.S.W., and S.W. by W. winds, minus one per cent. was adopted, and in the case of E.N.E., E. by N., and E. winds, no correction was applied; there were also a few exceptional days when special wind corrections had to be decided upon.

Experiments on varying the height of tubes.

The next question investigated by the Committee was the effect produced upon the upcast in the tubes by altering the height of the tubes. Experiments of this description were made at the Verification House close to the Observatory.

A ground plan and two cross sections of this Verification House are shown on diagrams 44 and 45. It should be observed that the longer axis was from E.N.E. to W.S.W.

Verification House, Kew Observatory.

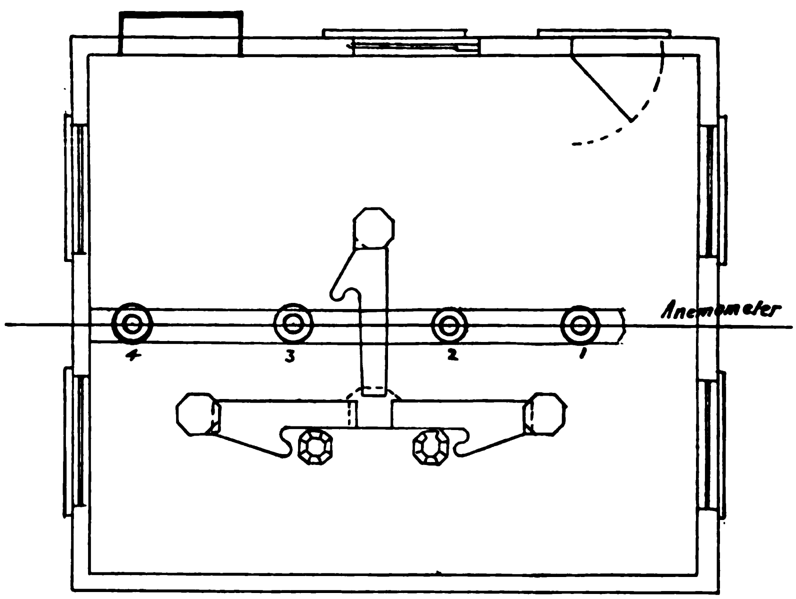


Diagram 44.

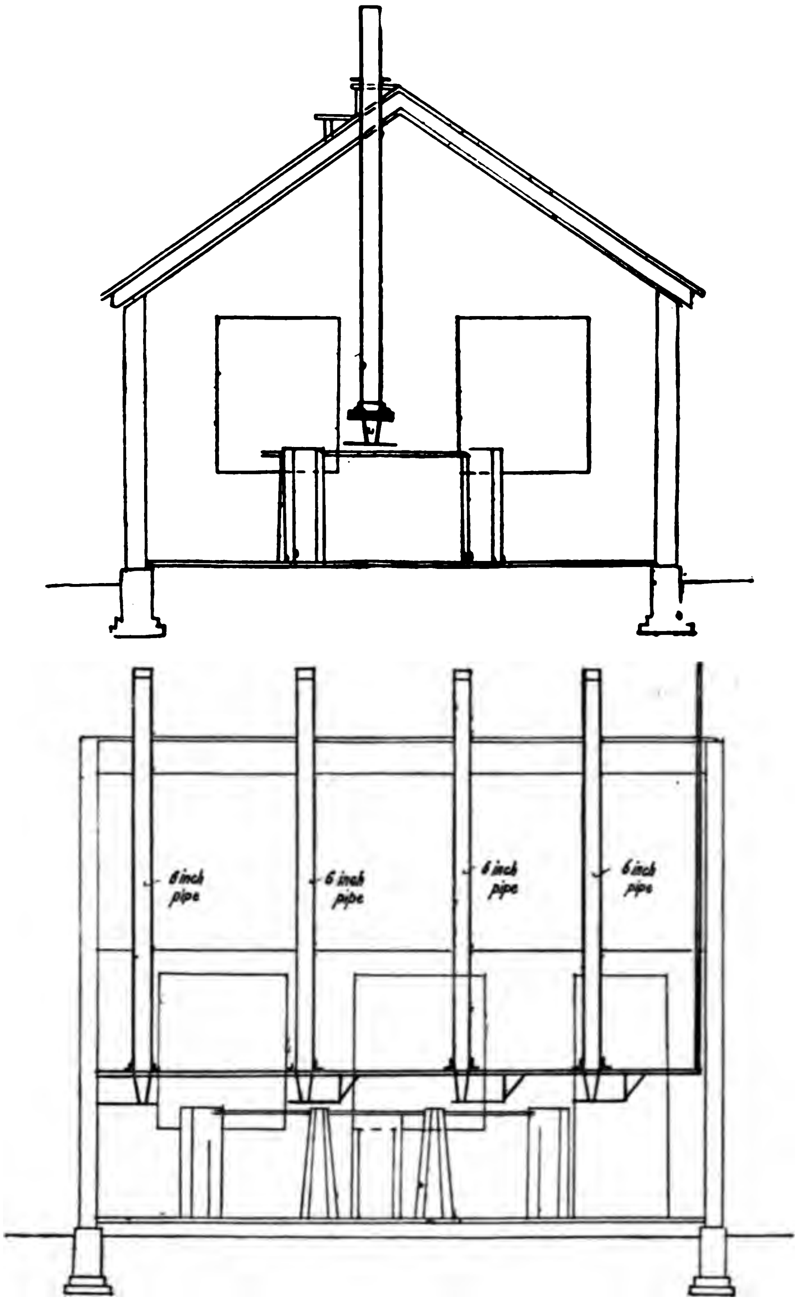


Diagram 45.

Experiments on Open Pipes of the same Height at the Verification House, Kew Observatory, 1878.

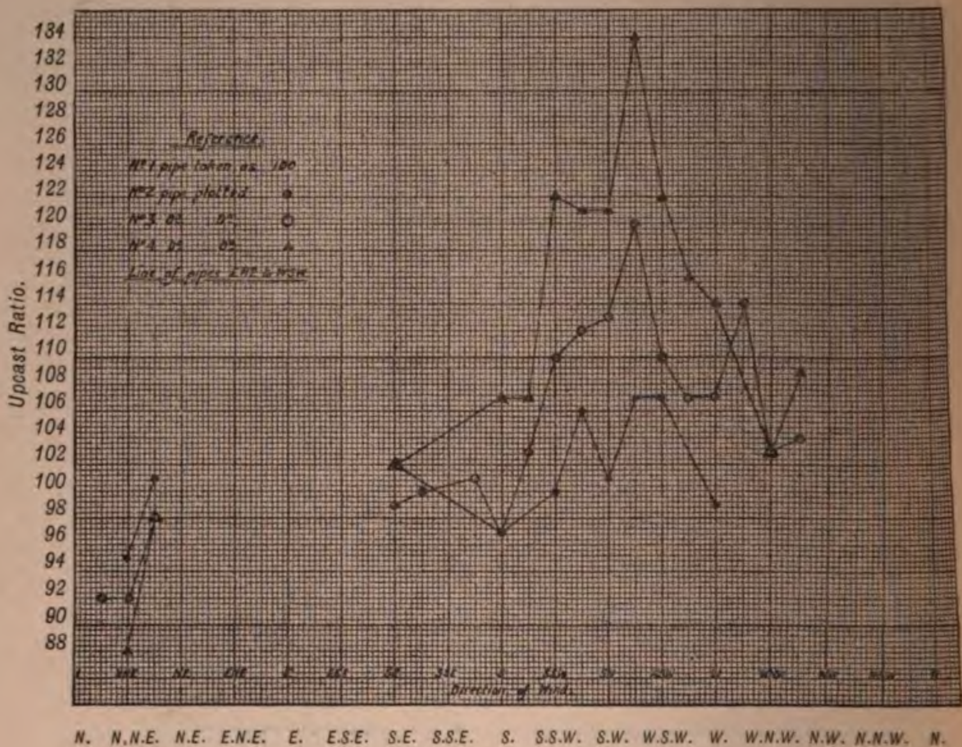


Diagram 46.

Experiments on Open Pipes of different Heights at the Verification House, Kew Observatory, 1881.

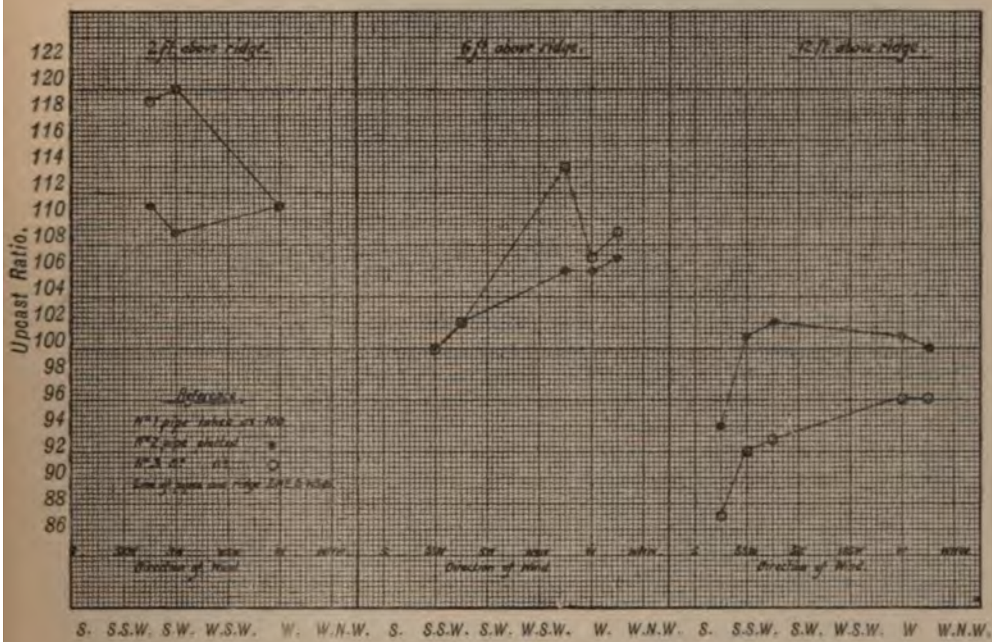


Diagram 47.

Through the roof of the building four iron tubes 6 ins. in diameter and 12 ft. long were fixed so as to project about 2 ft., leaving about 10 ft. within the building. The lower ends were fixed to a wooden bench. Four 3-in. air meters supported on a suitable table were placed, for the 3-in. experiments, under the lower ends of the tubes, and converging pieces of zinc were made to reduce the 6-in. iron tubes to the 3-in. air meters, the diameter of the inside ring of which was 2·7 inches. The air meters were controlled by two operators by means of wires so as to start and stop the instruments simultaneously. The duration of each experiment was ascertained by a chronometer, and the temperature inside and outside the building taken. At the Eastern end of the Verification House a Robinson Cup Anemometer, 4-ft. diameter from centre to centre of cups, was set up to record the velocity of the wind.

At the Verification House experiments on heightening of the pi
were made in 1881 with 6·1-in. air meters. These tests were averag
in blocks of three experiments or more, and the ratios of pipes Nos
and 3 calculated, pipe No. 1 being taken as the standard = 100. T
results were sorted according to the direction of the wind and plotted
Diagrams 46 and 47:—

The measurements show considerable differences between individual experime
The following Table indicates the extent of the variations. In the early Incide
Experiments the following differences were shown in the ratios of Pipe C (see Auxili
Paper, No. 45):—

	Max.	Min.		Max.	Min.		Max.
N.	108	91	S.E.	102	95	W. by S.	109
N. by E.	125	92	S.S.E.	100	97	W.	110
N.N.E.	99	95	S.	100	94	W. by N.	108
N.E. by N.	103	93	S. by W.	123	81	W.N.W.	108
N.E.	107	91	S.S.W.	110	93	N.W. by W.	97
E.N.E.	106	91	S.W. by S.	105	92	N.W.	104
E.	105	91	S.W.	110	91	N.W. by N.	103
E. by S.	101	91	S.W. by W.	109	99	N.N.W.	109
E.S.E.	103	96	W.S.W.	110	93	N. by W.	107

The later Incidental Experiments showed the following differences see (Auxil
Paper, No. 46):—

	Max.	Min.		Max.	Min.		Max.
N.	104	94	S.E. by E.	105	93	W.S.W.	110
N. by E.	113	92	S.E.	104	96	W. by S.	109
N.N.E.	108	96	S.E. by S.	104	97	W.	110
N.E. by N.	108	92	S.S.E.	103	97	W. by N.	108
N.E.	100	91	S. by E.	103	99	W.N.W.	108
N.E. by E.	100	91	S.	105	95	N.W. by W.	97
E.N.E.	98	91	S. by W.	123	81	N.W.	104
E. by N.	101	92	S.S.W.	110	93	N.W. by N.	103
E.	106	92	S.W. by S.	105	92	N.N.W.	109
E. by S.	106	92	S.W.	110	91	N. by W.	107
E.S.E.	104	92	S.W. by W.	109	99		

Other experiments with a similar object were subsequently made at
Hut in the Old Deer Park.

A description of the construction of the Hut and of the apparatus
is given on page 259. The experiments made there to ascertain the e
of heightening the pipes were of two types.

The first type consisted of open pipe experiments with a flat roof, in which the orifice of the pipe was 1 ft., 2 ft., 4 ft., 4 ft. 7 in., 6 ft., and 10 ft. 9 in. respectively above the level of the platform representing the flat roof. Preliminary trials were made on short open pipes 4 ft. 7 in. above platform, with all three openings at the same level. To institute a comparison of their results with those of the long open pipes 8 ft. 3 in. above platform, the difference per cent. between the upcast of the centre pipe and the mean of the upcasts of the outer pipes was calculated. In this comparison the short open pipes were treated in the same way as the early experiments on long open pipes, *i.e.*, the only experiments regularly excluded were those in which the outer pipes differed by 10 per cent.; in the later open pipe experiments, those with light winds (below nine revolutions per minute of the cups of the anemometer) were also excluded. The great irregularity of the early experiments on short open pipes (so far as difference per cent. between centre pipe and mean of outer pipes is concerned) will be seen by the following comparison with the results of the early experiments on long open pipes:—

	Short Open Pipes.		Long Open Pipes.	
	No. of Experiments.	Per cent. of Total Number.	No. of Experiments.	Per cent. of Total Number.
All Experiments except those in line of pipes ...	33		286	
Experiments in which the difference of Upcast in Centre Pipe from that in Mean of Outer Pipes is $\pm$ 4% or less	19	58	269	94
" " " ... 5%	3	9	11	4
" " " ... 6% or 7%	3	9	6	2
" " " ... 8% or more	8	24	0	0

The preliminary trials were then tabulated in a similar form to that in which the regular experiments had been, and the ratios of upcast in the two outside open pipes calculated, taking Pipe A = 100.

From a general examination of the above results, the ratios appeared to be different in short pipes from what they were in long pipes.

The experiments on the effect of lengthening 6-in. pipes at the Verification House in 1881 showed that in the case of short pipes the

pipe against which the wind first struck had a greater upcast than th
other pipes, but with long pipes the reverse was the case.

The preliminary trials on short 3-in. open pipes at the Hut in 188
compared with the early long open pipes showed the same thing, only in
less degree.

Experiments were also carried out at the Hut with the outside pip
lengthened to 10 ft. 9 in. above platform. The results were tabulated an
averaged, and were found to practically agree with the results obtaine
from experiments in which open pipes of the usual length, 8 ft. 3 in.
8 ft. 7 in. above platform, had been tried.

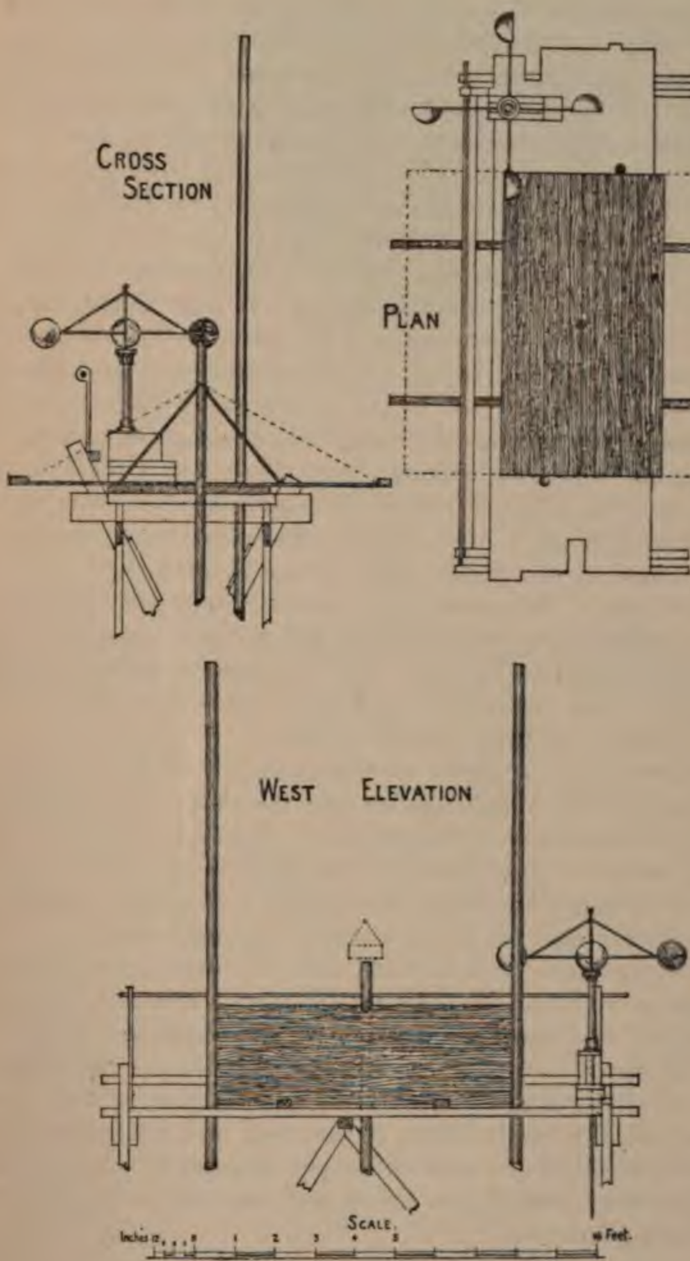
The results of experiments in which the orifice of the centre pipe w
1 ft., 2 ft., or 4 ft., and outside pipes 8 ft. 7 in. above platform, are show
in Table XXVI. on page 338.

The second type of experiments upon the effect of lengthening pip
consisted of experiments with a sloping roof, the object being to ascerta
how open pipes acted when placed close to the ridge of a sloping roof
compared with the same pipes extended so as to show a long vertic
shaft. Similar experiments were made at the same time upon a fe
terminals and one form of cowl, and the results of these experiments a
included on p. 444 with those of the open pipe experiments.

Some initial tests were made by fixing on the platform a sloping scre
on each side of the centre pipe at an angle of 52 degrees from th
horizontal. This screen consisted of a wooden frame 6 ft. long, set wi
ends equidistant from the centre pipe and covered with American clot

The outside pipes remained at their usual height, 8 ft. 3 in. to 8 ft. 7 i
above platform, but the centre pipe was fixed 4 ft. 7 in. above the platfor
or 2 ft. above the ridge which surmounted the original platform. The co
and terminals selected for trial were of two kinds, the one having an op
base and the other a closed base. Those with a closed base were
ordinary open pipe, a well known form of cowl, and an open pipe wi
enlarged end so as to form a solid cylinder with a pipe through the cent
and a conical bottom. The form with open base consisted of a sing
louvre, with inverted rain-gauge cap superposed (see Diagram 81, p. 42
fig. BZ).

The results showed that the upcast was considerably affected by t
angle at which the wind struck the screen. The plain open pipe whic
when placed on a long vertical shaft gave an efficiency of 1·00, w
reduced to ·80; the cowl with a normal efficiency of ·99, was reduced



Diagrams 48 and 49.

·76; and the terminal with open base, which gave an efficiency of 1·30 o a shaft, was reduced to ·98. From a close observation of the dial reading by the operator simultaneously with an observation of the variation in th direction of the wind, considerable difference in the efficiency was note according to the angle at which the wind struck the sloping roof.

For the regular experiments, two larger sloping roofs constructed c matchboard 7 ft. 9 in. in length were substituted for the screen abov described. As the edge of each sloping roof projected beyond the outlir of the stage, wooden supports were bolted to the platform to receive th roof in use. The outside pipes were raised 2 ft. 6 in. higher than whe working without roof for two reasons, firstly to insure the upcast in th pipes being uninfluenced by the roof, and secondly to admit an unobstructe length of pipe equivalent to the length when working without roof. Th details of these constructions will be seen from Diagram 48, p. 335.

Experiments were tried with the centre open pipe 1 ft., 2 ft., 4 ft and 6 ft. above the ridge of roof at 30 degrees in winds varying fro N.W. by N. to S.W. by S. only. These experiments were averaged, ar their results entered in a table. The average ratios between the cent pipe and the mean of the outside pipes varied from 92 per cent. when tl wind blew at right angles to the ridge to 110 per cent. when wind blew an angle of 45 degrees to the ridge. The experiments indicated that whe the centre pipe was raised the variation in the ratios became less, shown in the appended Table XXVI., p. 338.

The two roofs, *i.e.*, at angles of 30 degrees and 52 degrees were the compared to ascertain which angle affected the efficiency of the open pi more, when it was observed that the latter produced the greater chan with winds about at right angles to the ridge of the roof. The ro at a slope of 52 degrees from the horizontal was therefore selected as t one upon which to carry out the tests upon cowls and terminals.

As open pipe tests were required both to correct the sloping ro experiments on cowls and terminals for the particular angle correspondi with individual wind directions, and also to form a standard with which compare the upcast in the cowl or terminal, experiments with plain op pipes one foot above ridge of roof were usually made on each day prior proceeding with the regular work. These open pipe tests were collecte calculations made of the ratios of centre pipe to mean of outside pipes, a the results entered according to direction of wind and averaged in a tab in the following form :—

N.N.W.		N. by W.		N.	
Index Number.	Ratio.	Index Number.	Ratio.	Index Number.	Ratio.
7405	·96	7542	87	7864	78
8088	1·02	7543	90	7866	82
8086		8085	96	7869	85
				8010	77
				8013	83
				8014	80
3)	295	3)	273	6)	485
	98		91		81

The results were then plotted on diagram 50 (p. 339).

Experiments upon plain open pipes at heights other than one foot above the ridge of the roof are dealt with in the next Part of this report.

Table XXVI.—Giving Efficiency of Open Pipes of various Heights above Platform and Sloping Roof.

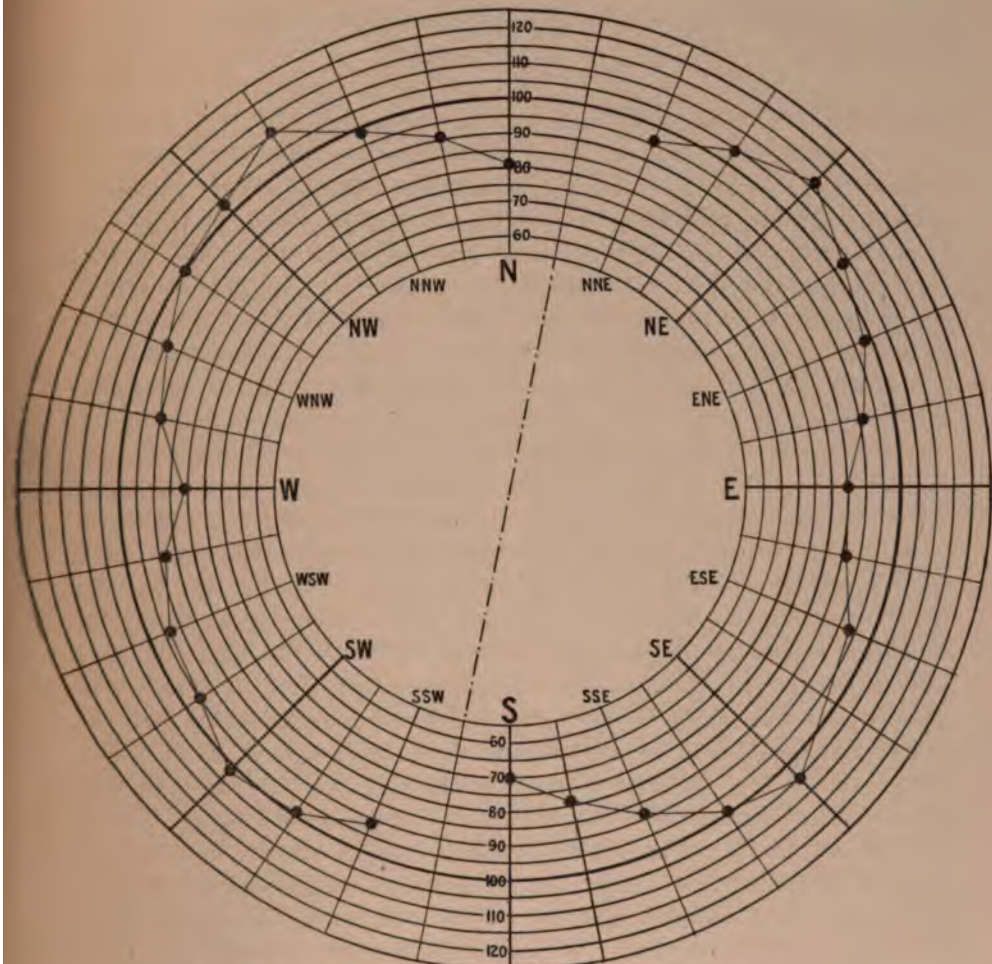
The Outside Open Pipes **A** *and* **C** *were 8 ft. 7 in. above Platform, and 5 ft. 11 in. above Ridge; Ridge 3 ft. 8 in. above Platform; 8 ft. 9 in. between Eaves.*

Height of centre Pipe above Platform or Ridge.	E. side of line of Pipes.					W. side of line of Pipes.														
		N.E. by N.	N.E.			S.S.W.	S.W. by S.	S.W.	S.W. by W.	W.S.W.	W. by S.	W.	W. by N.	W.N.W.	N.W. by W.	N.W.	N.W. by N.	N.N.W.	N. by W.	N.
FLAT ROOF OR PLATFORM.																				
1 ft.	...	...	...	...	...	...	104 101	...	...	..	...	113 115 111 111	111 110 98 98	102 99	99	97		...	..	.
2 ft.	...	...	...	...	...	...	...	...	...	...	118	116 115 116 117	...	...	...	..	.	...	...	...
4 ft.	...	...	...	...	...	...	...	...	...	...	..	113 113 115	...	...	...	..		...	..	.
4 ft. 7 in. ..	...	99 97	100 98	...	...	...	...	...	...	...	...	110 110	106 105 107	106 104	...	.	.	...	...	..
5 ft. 9 in. ...	...	...	...	...	...	...	...	...	...	...	...	...	100 103 102	...	...	..	.	...	...	...
8 ft. 7 in. ...	...	98	...	...	...	...	102	...	...	...	...	104 99	102 103 102 100 100	...	...	.	..	...	...	...
SLOPING ROOF, ANGLE 30°.																				
1 ft.	...	...	...	...	...	...	...	100	...	99 99 95	99	99 99	99 98 101	104	112 110 107	112	103	105	.	...
2 ft.	...	...	...	...	...	...	...	114	106	90	88	89 99	...	.	..	..	..	...	.	...
4 ft.	...	...	...	...	...	...	104	107 109	106 101	...	...	97 98 99	...	...	...	...	..	..	.	...

Old Deer Park.

Open Pipes—1 foot above Ridge of Sloping Roof, angle 52°.

(See also Diagram 81, p. 421.)



100 line shows mean of A and C; B plotted against this.

Diagram 50.

PART V.—EXPERIMENTAL RESULTS FOR TERMINALS AND COWLS.

Introductory Note on the Experiments on the "Efficiency" of Cowls and Terminals.

It was the intention of the Committee to assign a number, or a series numbers as might be found necessary, to indicate the efficiency of the C or Terminal under consideration. The numbers were to indicate the eff of the terminal or cowl upon the flow up a 3-in. pipe. The efficiency to be indicated by the factor by which the computed rate of flow up plain open 3-in. pipe must be multiplied in order to give the flow wh had been observed to take place up the pipe when surmounted by the C or terminal under identical conditions. In considering the application this method, it will be well to consider briefly the conditions govern the flow of air up a pipe under circumstances similar to those prevailing the Hut, and it will be seen that the effect of a Cowl or Terminal can usually be regarded as being completely dealt with by a single factor series of factors, representing efficiency even for a single set of conditi as to the direction and force of the wind under which the flow takes pl

We may premise that the flow of air along any particular pipe depe upon two conditions, namely, (1) the head or aëromotive force, and (2) resistance which the air will meet with in its flow. The effective m nitude of either of these elements is the resultant effect of a numbe separate causes. Each of them can be expressed numerically, but numerical expression is a very complicated one and not easily evaluate any particular case. If the aëromotive force and resistance be both s ably expressed numerically, the flow may be taken as the square roo the ratio of the aëromotive force to the resistance. It will thus be s that the flow in any particular case will increase if the aëromotive forc increased, and be diminished if the resistance is increased, and *vice ve* In computing the magnitude of each one of these elements the w course of the air from the outside of the Hut to the outside again at top of the pipe must be taken into account. If we consider the spe circumstances of these experiments, it will be seen that the productio the aëromotive force which causes the flow along the pipe is an extren complicated phenomenon. We have first to take account of the effec

the wind blowing across the mouth of the pipe, cowl or terminal. This depends upon the rapidity and completeness with which the air flowing up the pipe is removed from the opening. The rapid removal of the air causes a diminution of pressure at the opening of the pipe, and in consequence a flow. The diminution of pressure is liable to alteration, by alteration of the size or shape of the orifice, or by anything else which affects the eddies caused by the wind passing over the pipe. A further circumstance to be considered is the air pressure inside the Hut. The wind impinging upon the face of the Hut finds its way into the interior through the numerous crevices between the boards, and if there were no pipe it would have to find its way out again through the crevices in the other sides. It depends upon the relative distribution of these crevices whether there is on this account alone a lower or a higher pressure in the interior of the Hut than that in the uninterrupted wind near the mouth of the pipe; in other words, it depends on this distribution of crevices whether the air driven into the Hut on the windward side will use the pipes as an outlet, and so flow upwards, or the pipes will help to supply by means of a down-draught the air demanded by the reduced pressure on the lee side of the Hut.

A third element in the calculation of the aëromotive force is the temperature of the air in the vertical pipes. If there is any difference, no matter how small, between the temperature of the air in the pipes and that of the external air, the aëromotive force is affected; increased if the air in the pipes is at a higher temperature, decreased if it is lower than the external air.

The complexity of the conditions upon which the effective aëromotive force depends has sometimes been the cause of misunderstandings with respect to the action of cowls. Thus in the first report of the Cowl Committee the flow observed was assumed to represent the action of the Cowls; in a letter of protest from Mr. Baldwin Latham to the Secretary of the Sanitary Institute, dated 6th of June, 1878, the conditions under which the Cowls were tested were referred to as being such that the Cowls only acted as obstructions to ventilating tubes. The real state of things is that the action was a complex one, depending upon both the Cowl and the temperature, and it depends upon the details of the arrangements as indicated herein whether the effect of the cowl, or the effect of the ventilating tube, constitutes the predominant feature of any particular experiment.

Some idea of the effect of temperature differences upon the experiments under consideration should be gathered from a tabular statement

in which the readings of upcast are given, as well as the correspondi temperatures read on thermometers introduced into the pipes. But t table does not give much information, for in the first place the therm meters in use were not altogether trustworthy, and secondly, their prese in the pipes necessarily interfered somewhat with the flow. It inclu nineteen experiments corresponding to various wind directions, and fr the averages of pipes A and B it would appear that the effect of a differe of temperature of one degree in the air of the pipes might cause a 10 cent. difference in the readings, but it would not be safe to rely upon t result, for in the same table nearly the same difference is shown betw pipes B and C without any observed difference of temperature.

Again in considering the other element which affects the flow, resistance, every part of the circuit must once more be taken into accou The resistance in the cases under consideration is made up of many par the aëromotive force, however produced, has to carry the air through crevices of the Hut, through the silk gauze screens covering the botto of the boxes at the foot of the pipes, past the air meters, along the 23 f length of pipe and through the Cowl or Terminal at its head. All th parts of the circuit cause resistance and the effective resistance of whole depends upon the combined effects of the several parts. A C placed upon the upper opening of the pipe may modify both the aëromot force and the resistance: the transition from an exhaust Cowl to injector may be made by successive steps, yet it is evident that in injector the direction of the aëromotive force is reversed from that of exhaust cowl, and is of sufficient magnitude to overcome any ot aëromotive forces affecting the flow in the special case. If with particular form of cowl the direction of the aëromotive force is rever it is usual to call the reversed flow "downdraught," but it is evident t if the pipe is provided with a bend which makes its orifice vertical delivers its air horizontally, then there will be a gradual transition fr maximum suction to maximum injection as the head is gradually revol with regard to the wind. Again, a cowl which restricts the passage the air along the pipe adds to the resistance, while at the same time aëromotive force may not be affected. It may be possible to arrang circulation so that the addition of an apparatus like a cowl may aff only one of the elements, aëromotive force or resistance. If the cowl w mounted upon the top of a pipe which already offers very great resista to the flow of air, the additional resistance of the cowl itself might quite inappreciable; for example, when a cowl is mounted on the extrem of a long and tortuous drainage system, the resistance to flow of air alre

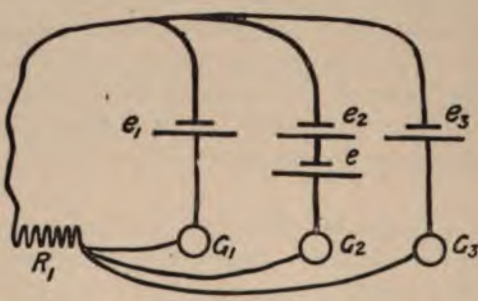
existing will be very large and the cowl will not sensibly add to it, so that any effect which the cowl produces will be attributable to the modification of the aëromotive force which would otherwise have been produced; and on the other hand the same cowl placed upon a plain pipe of ample dimensions through which air is being driven by wind may not sensibly affect the aëromotive force, but may add very substantially to the resistance and so affect the flow.

The effect of varying the resistance to the flow of air without varying any other elements may be seen by considering the results of experiments upon the use of Air Meters in the inverted position. These have already been described in Part II. of the Report (p. 265), and a tabular statement given showing the maximum, minimum, and mean ratios derived from 180 experiments. The differences between the measurements for experiments, which differ only in the direction of the flow of air through the meter, are as large as 22 per cent. in one series, and not less than 12 per cent. in any. They may be attributed to the fact that the Air Meter has a higher resistance for flow in the one direction than in the other. The increased resistance may be due merely to the shape of the meter, or it may require more power to drive it in the one way round than in the opposite. It is understood that Mr. Rogers Field attributed the difference to the greater friction of the spindle in the reversed position, or to the different effect of the boss of the meter in the two positions upon the flow of air.

It is clear from these considerations that the efficiency of a Cowl ought to be estimated with regard to the circumstances under which it is to be used. If it is to draw air from what practically amounts to a very nearly closed space, its resistance to flow may be disregarded, and its efficiency estimated according to its capacity for producing aëromotive force, but in most cases of ventilation its effect upon the resistance must also be taken into account, and in specifying the efficiencies both effects ought to be represented. Now in the experiments of the committee the circumstances were peculiarly complicated. If we trace the air along its course, from outside to outside of the shed through these pipes, we have clearly three parallel circuits with some common elements; thus all three circuits share the crevices of the hut, they share also the aëromotive force due to any compression or rarefaction of the air in the interior of the hut, but each pipe has its own aëromotive forces dependent upon temperature and on the air passing over the upper opening, and the effect of any particular wind upon the flow will depend upon the way in which, under the circumstances, the three pipes distribute the flow between them, and will be dependent

upon the aëromotive forces and the resistances of all three circuits. T numbers so obtained for ratios of flow will accordingly not give anythi which can be regarded as a "constant" for the Cowl, or which will se to identify the effect which the Cowl would produce in the way of alte tion of aëromotive force, or alteration of resistance in circumstan slightly different. The numerical result is, in fact, due to the spe combination of circumstances, and could not be reproduced unless circumstances were themselves approximately reproduced.

The laws of flow of electricity are now so generally understood th may be pardoned for illustrating the uncertainty of the experiments, fr the point of view of the determination of a constant of efficiency fo cowl by the electrical analogy. We may regard the three pipes as th battery circuits. Each has its own electromotive force e_1 e_2 e_3 its own resistance r_1 r_2 r_3; the three circuits have, however, a comm part, R_1 representing the crevices of the Hut. We shall, theref represent the state of things diagrammatically, thus:—



As the flow in each circu to be separately measured electrical analogy must pro a galvanometer for each of three circuits, G_1, G_2, The addition of a cowl on of the tubes will correspon the insertion of an additi battery cell in the middle cuit G_2, with its appropr electromotive force e and resistance r. Electrical students will at realise that the alteration in the flow through the galvanometer G_2, sequent upon an insertion of e, will produce alterations in the flow thro G_1 G_3, and consequently that the constants of the added battery can be determined if the electromotive forces e_1 e_2 e_3 and the resista r_1, r_2, r_3 and r be already known.

But although the numbers obtained for the ratio of the flow along pipe carrying the cowl to the flow without the cowl give us nothing can be regarded as a constant for the cowls, and consequently the us the term "efficiency" to denote the ratios obtained is inappropriate, experiments in themselves give a great deal of information of great va and the measurements are accordingly reproduced here with the nota adopted by the committee.

The committee drew a distinction between a Cowl and a Term

which has already been referred to in Part IV., p. 298. The greater number of the Terminals are of such a shape that they do not appreciably add to the resistance of the circuit, and their effects must be attributed to the change produced in the aëromotive power of the central pipe. The results speak for themselves. They show that it is possible by modifying the terminals to increase the ratio by as much as 50 per cent. W.N.S.]

The experiments for the investigation of the effect of different Terminals and Cowls were made at the Hut in the Old Deer Park. It has already been described, and particulars of the arrangements for mounting the Cowls and Terminals (p. 259), for measuring the flow in the three pipes (p. 297), and for reducing the readings of the outside pipes to the equivalent of the centre pipe (Part IV.) have been given already, and it is unnecessary to repeat them, but the following notes of casualties during the course of the experiments should be mentioned.

1. On April 2nd, 1895, some necessary repairs were carried out, and on the 5th April, Mr. Rymer Jones, who then had charge of the experiments, found that the North-east end of the Hut had subsided to such an extent that the tops of the pipes were from three to four inches out of the vertical. This was remedied by moving the meter boxes a corresponding amount towards the North-east.

2. Between May 11th and May 19th, 1897, it is noted that the weather boards, door and windows of the Hut, which had been gradually getting into a state of disrepair, were renewed, so that from this time the fitting of the woodwork was somewhat closer than immediately before that time.

3. On February 1st, 1898, the South pipe showed externally signs of the joint being defective, and it was accordingly tested with smoke to ascertain whether there was any leakage. The pipe, however, proved to be sound.

4. On January 2nd, 1899, the centre pipe was found to have parted at the seam just above the roof of the Hut. It was made smoke-tight by the use of red-lead and gold-size. The two outside pipes were tested at the same time and found to be sound.

The experiments extended over the period from 1884 to 1900.

The results of the experiments upon Cowls and Terminals are contained in nearly 200 sheets of the Complete Tabulation, including over 1,300 sketches. The plan adopted was to mount the Cowl or Terminal upon the middle one of the three 3-in. pipes erected at the Hut, to take the mean

of the readings of the air meters in the two outside pipes, with correction as described in Part IV., as indicating what would have been the rate o flow up the middle pipe if there had been no Cowl or Terminal on the to of it, and to compare the actual reading for the centre pipe with the mea so obtained. The direction of the wind and an anemometer reading wer taken for each experiment. The recorded direction was made use of t compute the appropriate correction for reducing the mean of the outsid pipes to the equivalent of the centre pipe, using the "compasses" compile for that purpose and reproduced in pp. 302–327.

The times occupied by the several experiments were very various: i the early experiments they lasted over 10 or 20 minutes, but in the bul of the later tests they were for five minutes, except that a number o experiments of two minutes each were occasionally taken on the same da in order to complete a series in the one day. The results of these speci series of experiments, which are known as Hill curves, are represented i diagrams 37–43, p. 315.

The records of the experiments were carefully examined and abstracte in order that any obvious abnormalities might be dealt with before th results were allowed to stand in the Complete Tabulation. In a mem randum prepared in 1895, when about 2,000 experiments had been mad it is shown that upon examination experiments were rejected for vario causes as follows:—

65 because the observer considered them unsatisfactory.
1 because on examination there was a doubt about the details.
17 because there was something wrong with the apparatus, or was uncertain which Air Meter was used.
51 because the experiment corresponded with an anemomet reading below 9 revolutions of cups per minute.
153 because the upcast velocities in the outside pipes showed difference of 10 per cent.

In the later stage of the investigation experiments were rejected f similar reasons before they were transferred to the sheets of the Comple Tabulation, but the percentage of experiments rejected in the later wo was very small.

In explanation of the system of averaging efficiencies upon the Co plete Tabulation, it may be noted that in cases where the construction the Cowl or Terminal is such that it gives, or may give, different effici cies, according to the different positions of the cowl or terminal as rega the wind, a separate average is as a rule given of the efficiencies for ea

position of the Cowl or Terminal. These separate averages are entered, and their general average given in the following way:—

$$\left.\begin{array}{l}\left.\begin{array}{l}\text{·97 is the average of experiments with}\\ \qquad\text{shutter of Cowl to wind.}\end{array}\right\}\text{·97}\\ \left.\begin{array}{l}\text{1·06 is the average of experiments with}\\ \qquad\text{opening of Cowl to wind.}\end{array}\right\}\text{1·06}\end{array}\right\}\text{1·02}$$

1·02 is the average of ·97 and 1·06, and is thus the general average efficiency of the cowl. It may be noted that in the arithmetical processes the last figure retained has been raised by unity whenever the fraction omitted was ·5 or more.

The reproduction of all the separate experimental results which have been finally approved and are included in the Complete Tabulation, would occupy a very large space, and in order to present to the reader a summary which will enable him to form an opinion of the performance of a Terminal or Cowl, the plan adopted in the following Table (XXVII.), p. 349, is to give the mean of the ratios obtained, as well as the maximum and the minimum, and the number of experiments from which the average has been obtained.

TABULAR REPRODUCTION OF RESULTS.

General Notes.

Square Types.—Terminals with square heads were set up both with the flat side to the wind and with the angle formed by the sides to the wind, but owing to the constant slight variation of the wind direction the results can only be considered as approximate. The same remark applies to other Terminals (such as those shown at sketches No. 40, 45, 54, 57) set up in more than one position for testing; also to Terminals with feather attachments, as shown at Sketches Nos. 127, 132, 149, &c., and to Cowls placed with opening or shutter to the wind.

Wind Direction.—The entries of wind direction have been made proceeding as the sun travels, viz., from N.N.E. through S. and W. to N., but this does not necessarily imply that experiments were tried in all directions of wind between the limits entered. In one instance (sheet LXVI. of Complete Tabulation at experiments 5041, &c.), the entry N.N.E. to N. might be read as wind from all quarters, whereas the Terminal was only tried in winds from N.N.W. to N.E. by E.

Downdraught.—In entering the data in downdraught columns the precise measurements shown on the sketch have not always been adhered to, but can be obtained by referring to the details on the Complete Tabulation. This method was

adopted for brevity, as in this class of test the primary consideration was to ascertain whether a particular type of Terminal was or was not subject to downdraught.

Cowls as Injectors.—As only two Injector forms of Cowls were tried, they have not been entered in the Tabular Reproduction of Results for Injectors (see Complete Tabulation, sheet CXCI.). A few preliminary trials were made with another Injector, but a special deduction had to be made in this case to allow for the non-inversion of the air meter (see Complete Tabulation, sheet CXC.). The use of air meters in the inverted position has already been explained at the conclusion of Part II., p. 265, of this Report.

Downdraught.—In testing for downdraught, the raingauge caps (see sketch No. 72, &c.) were mostly tried 1½ in. above the orifice of the open pipe, as in the early stages of the investigation this distance was considered the most effective.

Downdraught with Board.—In downdraught experiments with board, the Cowl or Terminal was sometimes fixed upon the centre pipe and sometimes upon one of the outside pipes.

Size of Base of Cowl.—As some of the Cowls are evidently constructed for fixing over, and others into, a 3-in. or 6-in. pipe, their spigot ends are not exactly 3 inches or 6 inches, but slightly more or less as the case may be.

General Conditions when Testing.

The tops of the outside open pipes in experiments with a Cowl or Termina on the centre pipe were usually 8 ft. 3 ins. or 8 ft. 7½ ins. above platform.

The door of the Hut was generally shut during the progress of upcast an Injector experiments, but open when testing for downdraught.

Caps and other additions to Terminals were mostly fixed by four wire stay from outside of band of cap to outside of the Terminal. In the later experi ments, chiefly upon the louvre and sugarloaf types of Terminals, feathers c gills were substituted for the stays to admit of a comparison between the tw methods of attachment.

Terminals with stays were generally set for the wind to pass between the stay

In the case of Terminals which were surmounted by caps, the orifice of th pipe, whether cylindrical or diverging, was at the same height as the outsic pipes, and the cap was placed above it; and in the case of Cowls, the middle the Cowl was placed on the same level as the orifices of the two outside pipes.

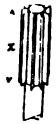
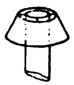
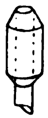
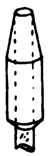
Reference Letters.

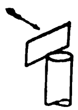
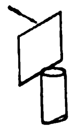
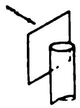
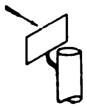
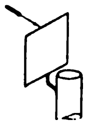
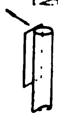
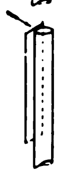
The following Reference Letters have been used herein:—

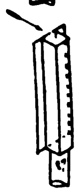
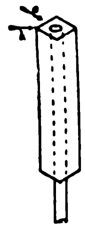
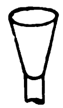
S	indicates	"Smoke Test."
I	„	"Injector."
DB	„	"Downdraught Test with Board behind centre of Terminal
R	„	"Sloping Roof Test."

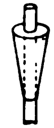
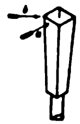
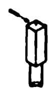
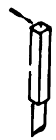
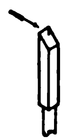
The drawings in the following Table are in proportion, but not all to tl same scale. The Terminals up to No. 214, p. 385, were all fitted to 3-in. pipe

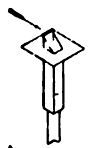
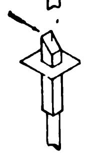
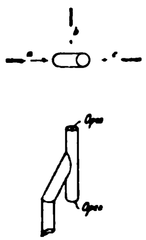
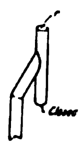
Sheet of complete Tabulation.	Date.	Sketch of Terminal.		Velocity of Cups, feet per minute. Max.	Min.	Direction of Wind.	Efficiency. Max.	Min.	Average.	Number of Experiments.	Reference Letters.	Angle from vertical at which downdraught is observed.	Remarks.
I. to IX.	Various.	1 	....	......	......	....	......	......	100 Standard.	306	S DB R	A = down-blow. B = up-blow. A 20°	1. In this tabular reproduction the Open Pipe is taken at 100 for standard purposes, although the general average experimentally obtained requires correction, as indicated by the Compasses described in Part IV. In Open Pipe tests the upcast was found to vary considerably according to the particular day upon which the experiments were made, and for this reason: an Open Pipe test was usually made at the start of the day's work. For the same reason series of experiments (such as those plotted, figs. A E to A J, pp. 405 to 409) were carried out on the same day or days. No Open Pipe tests have been made with an angle or bend in the pipe in its course from the interior to the exterior of the Hut. The nearest approach to this arrangement is shown at Sketch No. 43, p. 355. For Sloping Roof results see p. 338, also figs. B W and C B, pp. 421 & 422.
XXXIII.	8 June, '97	2 	Dia. of bead $3\frac{3}{4}''$	595	508	From E. to E.N.E.	99	98	99	3	......		
XXXIII.	8 June, '97		" $4\frac{1}{2}''$	583	508	From E. to E. by N.	101	100	101	3			
XXXIII.	2 Aug., '87	3 	....	327	253	From N.W. to W.N.W.	91	90	91	3			
XXIX.	1 Aug., '87	4 	....	209	206	From N.W. to N.N.W.	85	80	83	2			
XXXI.	16 Mar., '98	5 	Wire $\frac{1}{12}''$	312	270	From W.N.W. to N.W.	102	101	101	3			
XXXI.	16 Mar., '98		Wire $\frac{3}{16}''$	322	264	From W. by N. to N.W.	101	98	99	3			
XXXI.	27 Aug., '84 28 Aug., '84 16 Mar., '98	6 	....	410	189	From W. to N.W.	100	95	98	5			2. This tends to show that an astragal or beading may be fitted on an Open Pipe without diminishing the efficiency, provided the width of the astragal is not excessive. This conclusion is confirmed by the results shown at Sketch No. 12, p. 350, and the plottings on figs. M and N, p. 400.
XXX.	27 Aug., '84 28 Aug., '84	7 	....	308	212	From W. to W.S.W.	73	70	72	2			
LVI^{H}.	20 Dec., '97	8 	$x=\frac{3}{4}''$	706	603	From E. to N.E. by N.	111	107	110	3	......	....	These experiments were made to compare with those for Sketch No. 131, p. 369. x=distance between top of pipe and top of feather.
LVI^{H}.	7 Jan., '98		$x=1\frac{1}{4}''$	445	289	From N.W. by N. to N.W.	108	97	105	6			
LVI^{H}	12 Feb., '98	9 	....	586	513	From S.W. by S. to S.W.	110	93	102	5	......	....	See also fig. L, p. 399.

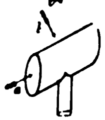
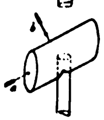
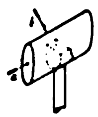
Sheet.	Date.	Sketch of Terminal.			Velocity of Cups, feet per minute		Direction of Wind.	Efficiency.			Number of Experiments.	Reference Letters.	Angle from vertical at which downdraught is observed.	Remarks.
					Max.	Min.		Max.	Min.	Average				
LVI$^{H.}$	14 Feb., '98	10		$x = 12''$	249	123	From W. by S. to W. by N.	109	102	106	4	......	....	See also Sketch No. 111, p. 365.
LVI$^{H.}$	14 Feb., '98 15 Feb., '98			$x = 18''$	661	156	From S.W. by W. to W. by N.	112	108	110	8			
XXI.	9 Sep., '84	11		....	193	154	W.	81	81	81	2			
XXI.	29 Aug., '84 30 Aug., '84	12		....	476	303	From W.N.W. to W.S.W.	79	74	77	2			
XXI.	12 Dec., '87 25 Jan., '88	13		....	570	118	From E. to S.W.	93	83	88	4			
XXI.	7 Sep., '87	14		....	319	181	N.W.	72	67	70	3			
XXVII.	7 Oct., '87	15		....	224	149	W.N.W.	97	92	94	4			
XXVII.	14 Jan., '88 25 Jan., '88	16		....	596	116	From S.E. to S.W.	96	98	97	2	......	....	A similar terminal with 9-in. Raingauge Cap 1½ inches above, and cylindrical part of Drum produced to 28 inches, gave downdraught in position B at 40°.
XXIII.	6 Sep., '87	16a		....	586	463	S.W.	117	115	116	3	......	....	The effect of fixing Raingauge Cap above this terminal is somewhat

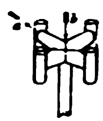
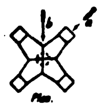
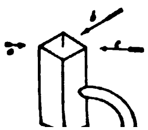
LVI^{E}.	7 Dec., '97	17		....	......	.....	S.W.	114	112	113	3				
LVI^{E}.	7 Dec., '97	18		....	......	......	S.W.	......	......	103	1				
LVI^{E}.	7 Dec., '97	19		....	......	......	From S.W. to S.S.W.	107	105	106	3				
LVI^{E}.	7 Dec., '97	20		.. ..	......	......	From S.W. to S.S.W.	117	115	116	3				
LVI^{E}.	7 Dec., '97	21		....	....	......	From S.W. to S.S.W.	......	......	109	1				
LVI^{E}.	15 Dec., '97 20 " "	22		....	792	742	From E. by N. to W.S.W.	110	107	109	6	......		....	See figs. J and K, p. 399 (plate 6 inches wide).
LVI^{E}.	15 Dec., '97 20 " "	23		....	266	206	From E. by N. to W.	124	106	115	7	.....		....	See figs. J and K, p. 399 (plate 6 inches wide).
XXVII.	26 Sep., '87	24		...... *a* ...... *b*	394 420	352 387	W. W.	112 78	111 75	112 77	2 2	......		....	The large difference observed in the efficiency is probably due to the position of the terminal in regard to the wind direction.
XXV.	16 Aug., '87	25		....	282	206	From E. to E.N.E.	105	103	104	4				

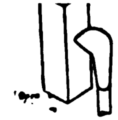
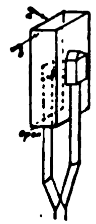
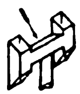
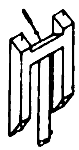
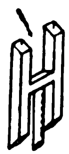
Sheet	Date	Sketch of Terminal		Velocity of Cups, feet per minute Max.	Min.	Direction of Wind.	Efficiency. Max.	Min.	Average	Number of Experiments.	Reference Letters.	Angle from vertical at which downdraught is observed.	Remarks.
XXV.	18 Aug., '84 19 Aug., '84 9 Sep., '84	26 	....	370	152	From S.S.W. to W.	114	112	113	4			
LVI[F].	15 Dec., '97 20 Dec., '97	27 	....	681	603	From E. by N. to S.W.	116	105	111	5	......	....	See General Notes re square types.
XXVIII.	25 Nov., '87	28 	...... a b	251 260	231 228	From W. to W.S.W. W.	122 111	111 98	117 108	3 3	......	....	See General Notes re square types.
LIV.	29 Aug., '84 30 Aug., '84 9 Apr., '95	29 	....	571	202	From S.W. by W. to W.N.W.	125	118	122	5			
LVI.	9 Apr., '95	30 	.. ..	546	498	From S.S.W. to W.S.W.	119	117	118	3			
LVI[D].	12 Aug., 97	31 	....	302	191	From W. by S. to W.N.W.	123	120	121	3			

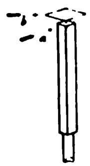
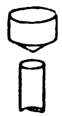
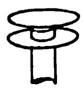
LVI$^{D.}$	10 Aug., '97	33		....	362	327	From S.S.W. to S.W. by W.	132	130	131	3			
LXIII.	26 Apr., '95	34		....	593	269	From S.W. by S. to W.S.W.	108	105	107	4	......	....	For comparison with flange on 3-in. pipe, see fig. N, p. 400.
LVI$^{D.}$	12 Feb., '98	35		...... *a*	608	583	From S.S.W. to S.W.	131	130	131	2	......	....	See General Notes *re* square types.
				b	626	616	From S.S.W. to S.W. by S.	107	104	106	2			
LVI$^{F.}$	15 Dec., '97 20 Dec., '97	35a		....	821	749	From E.N.E. to W.S.W.	111	106	108	6	......	....	See General Notes *re* square types. See also fig. B, p. 397.
LVI$^{F.}$	15 Dec., '97 20 Dec., '97	35b		....	674	613	From E. by N. to W.S.W.	124	117	121	6	......	....	See General Notes *re* square types. See also fig. B, p. 397.
LVI$^{F.}$	8 Feb., '98	36		....	485	314	From W. to W.N.W.	127	126	127	3	......	....	For similar terminal with twirling top, see sketch No. 195. See General Notes *re* square types.
LVI$^{F.}$	20 Dec., '97 5 Feb., '98	37		....	737	352	From E.N.E. to N. by W.	132	130	135	6	......	....	See General Notes *re* square types. See also fig. Y, p. 403 (bevelled round pipe).

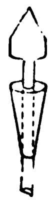
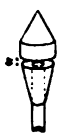
Sheet.	Date.	Sketch of Terminal.	Velocity of Cups, feet per minute. Max.	Velocity of Cups, feet per minute. Min.	Direction of Wind.	Efficiency Max.	Efficiency Min.	Efficiency Average	Number of Experiments.	Reference Letters.	Angle from vertical at which downdraught is observed.	Remarks.
$\mathrm{LVI}^{F.}$	5 Feb., '98	38 	515	420	From N.W. by N. to N.N.W.	127	125	126	3	......	....	See General Notes *re* square types.
$\mathrm{LVI}^{F.}$	5 Feb., '98	39 	488	354	N.N.W.	127	124	126	3	......	....	See General Notes *re* square types.
$\mathrm{LVI}^{K.}$	1 Feb., '98	40  *Plan.* ... *a*	603	302	From W. by S. to W. by N.	99	94	96	4	......	....	See General Notes *re* square types. The primary object of this well-known construction is to obtain a terminal which will be proof against both rain and downdraught. The terminal was tested in three positions, in order to ascertain the most effective setting to the prevailing wind. Compare also Sketches No. 57 & 58, p. 356.
$\mathrm{LVI}^{K.}$	3 Feb., '98 1 Feb., '98	... *b*	691	266?	From W. by S. to W.N.W.	107	103	105	6			
$\mathrm{LVI}^{K.}$	3 Feb., '98	... *c*	603	495	From W. by S. to W. by N.	95	91	93	3			
$\mathrm{LVI}^{K.}$	1 Feb., '98	41  ... *a*	498	453	From W.S.W. to W.	74	73	74	2	......	....	This terminal was closed at one end for experimental purposes only. Compare also Sketch No. 59, p. 357.
$\mathrm{LVI}^{K.}$	1 Feb., '98 3 Feb., '98	... *b*	591	299	From W.S.W. to W.N.W.	94	84	90	5			
$\mathrm{LVI}^{K.}$	1 Feb., '98	... *c*	292	239	From W.S.W. to W. by S.	85	84	85	2			

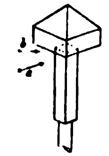
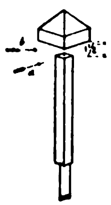
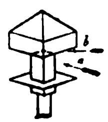
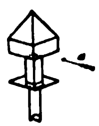
LVI[L.]	3 Feb., '98	44		.. ... b	676	613	From W. by S. to W.N.W.	97	96	96	3			
LVI[J.] LVI[J.]	7 Jan., '98 7 Jan., '98	45		...... a b	272 314	216 282	From N.W. to N.N.W. N.W.	41 101	30 101	36 101	2 2	....	....	See General Notes *re* square types. In position "*a*" the centre air meter was sometimes stationary, but no downdraught was observed.
XLI. XLI. XLI.	9 Sep., '84 9 Sep., '84 15 Sep., '84	46		...... a b d	470 228 253	432 228 253	W. W. E.	41	36	39 100 71	2 1 1			
LVI[J.] LVI[J.]	7 Jan., '98 7 Jan., '98	47		...... a b	277 206	153 158	From N.W. by N. to N.W. by N. From N.W. to N.W. by N.	24 101	? 100	? 101	2 2	.....	....	In position "*a*" the centre air meter was generally stationary, particularly when the wind blew directly through he horizontal tube, however no downdraught was observed.
LVI. LVI. LVI.	9 Apr., '95 9 Apr., '95 19 Sep., '84	48		...... a b d	480 548 414	390 385 414	From S.W. by S. to S.W. From S.W. by S. to S.W. by W. E.N.E.	61 120	61 110	61 116 87	3 5 1	.....	....	The vertical pipe was produced into the horizontal tube to create upcast, when he wind blew directly through the latter.
XLI. XLI.	11 Jan., '89 11 Jan., '89	49		...... a b	332 189	287 146	E. E.	28 112	25 105	27 109	2 2	......	See Remarks.	No downdraught observed. See also Remarks to Sketch No. 47.
XLII. XLII.	11 Jan., '89 11 Jan., '89	50		...... a b	184 302	138 201	E. E.	76 121	73 119	75 120	2 2	......	See Remarks.	No downdraught observed. See also Remarks to Sketch No. 48.
XLII. XLII.	11 Jan., '89 19 Jan., '89 19 Jan., '89	51		...... a b	314 402	148 402	From E. to N.W. W.N.W.	94 117	70 112	84 115	4 3	......	See Remarks.	No downdraught observed. By enlarging the produced vertical pipe in the horizontal tube it was anticipated that a better effect might be obtained, but the results show a compensating action, viz., as the efficiency in position "*a*" increases so the efficiency in position "*b*" decreases.

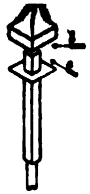
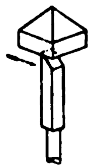
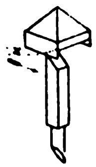
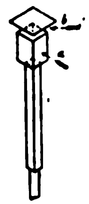
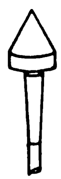
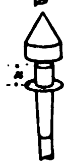
[illegible]	[illegible]	52		... a	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
[illegible]	[illegible]			... b	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
[illegible]	[illegible]	53		... a	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]			... b	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
[illegible]	[illegible]	54		... a	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]			... b	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
LVI.[illegible]	....	54a		...			....					[illegible]		
LVI.	23 Sep., '95	55		... a	571	294	From N. to W.N.W.	117	98	105	6		[illegible]	[illegible]
LVI.	10 Apr., '95			... b	490	338	From N. to N.W. by W.	130	100	113	4			
XLIII.	29 Oct., '87	56		... a	513	463	From W.N.W. to W.	109	108	109	[illegible]	[illegible]		
XLIII.	29 Oct., '87			... b	430	342	W.N.W.	107	105	106	[illegible]			
XLIV.	17 Dec., '87	57		... a	581	417	From W.N.W. to N.W.	99	96	98	8			[illegible]
XLIV.	17 Dec., '87			... b	586	543	N.W.	18	116	117	8			
XLIV.	17 Dec., '87			... c	470	416	From W.S.W. to N.W.	108	105	107	8			

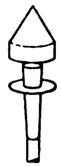
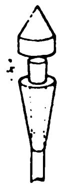
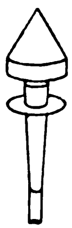
[illegible]	[illegible] 26 Dec., '87	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			
XLIV.	17 Dec., '87			*b*	674	573	S.W.	124	121	122	3			
XLIV.	17 Dec., '87			*c*	563	488	S.W.	122	121	121	3			
XLIV.	26 Dec., '87	59	Same as above, but closed at bottom.	*a*	422	284	N.E.	111	109	110	3	......	....	See Remarks to Sketches Nos. 41 and 42, p. 354.
XLIV.	26 Dec., '87			*b*	347	181	N.E.	118	111	114	5			
XLIV.	26 Dec., '87			*c*	337	116	N.E.	103	101	102	2			
XLV.	14 Jan., '88	60		*a*	299	194	E.	117	111	114	2	......	A 60°	
XLV.	14 Jan., '88			*b*	385	151	N.E.	114	106	110	3	......	B 60°	
LVI[J.]	26 Jan., '98	61		...	279	211	From S.W. by S. to S.W.	115	106	111	6	S DB	....	See General Notes *re* square types.
LVI[J.]	26 Jan., '98	62		...	231	143	S.W.	119	116	117	3	S		
LVI[J.]	26 Jan., '98	63		...	229	209	From S.W. by S. to S.W.	118	113	116	3	S		
LVI[J.]	26 Jan., '98	64		...	246	196	S.W.	125	124	125	2			
LVI[J.]	26 Jan., '98	65		...	226	181	S.W.	124	123	123	3	S		

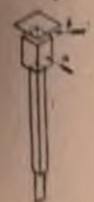
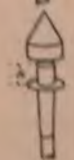
Sheet.	Date.	Sketch of Terminal.		Velocity of Cups, feet per minute. Max.	Min.	Direction of Wind.	Efficiency. Max.	Min.	Average	Number of Experiments.	Reference Letters.	Angle from vertical at which downdraught is observed.	Remarks.
												A = down-blow. B = up-blow.	
XXXVII.	21 Oct., '87	66 	...... a	322	180	From N. to N.E.	125	4	119	3	......	....	For similar terminal in circular form, see fig. T, p. 402. See also General Notes *re* square types.
XXXVII.	21 Oct., '87		...... b	375	184	N.E.	12	0	111	3			
XXXVII.	21 Oct., '87	67 	...... a	330	214	N.E.	30	20	25	3	......	See Remarks.	For similar terminal in circular form, see fig. U, p. 402. A similar 9-in. square plate was tried for downdraught 4 inches above a 3-in. square pipe 9 inches in length, when downdraught was observed in position B at 30°.
XXXVII.	21 Oct., '87		...... b	284	216	N.E.	10	09	10	3			
XXXVI.	29 Nov., '87	68 	....	277	242	W.S.W.	95	94	94	3	......	B 50°	Compare fig. R, p. 401.
XXXVI.	16 Jan., '88	69 	....	566	538	E.N.E.	101	99	100	2			
LXXXVI.	19 June, '96	70 	....	470	402	From S.S.W. to S.W. by W.	65	63	64	3	......	....	Also entered in Tabular Reproduction of the results for Cowls (see sketch No. 253), to compare with sketches Nos. 251 and 252.

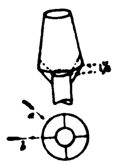
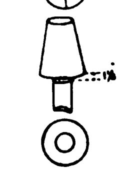
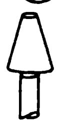
	23 Aug., '95 26 Aug., '95						... Raingauge caps generally. In constructing Raingauge caps for tests over 3-in. pipes, the principle invariably adhered to is that the length of the side of the conical portion (which may be regarded as merely a finish in preference to a flat top) is equal to the diameter of the cap, *i.e.*, in section the Conical part forms an equilateral triangle. For caps of various sizes at different distances above pipe, see special table, also figs. A E and A F, pp. 407 and 408. Similar terminal, but with plate in cap, gave downdraught when tried in position B at 50°.							fillet fixed on pipe 1½ in. down, gave downdraught when tried in position B at 30°. Similar terminal, but with an inverted conical ring, top level with orifice, gave downdraught when tried in position B at 30°. *For Sloping Roof results see p. 338 and 421, also figs. B Y & CC, pp. 421 and 423.
LVIII.	13 Apl., '95	73		Cap above pipe = 1″	508	442	E.	93	90	91	3	R*	See Remarks.	**73.** See also fig. O, p. 402. The object of adding this flange is to prevent downdraught from deflected winds. With flange 6″ down, no downdraught observed. With flange 9″ down, downdraught when tried in position A at 60°, and in position B at 30°.
XXXIV.	16 Dec., '87			„ = 1½″	586	410	W.S.W.	101	98	99	3			
LXIII.	5 July, '97	73a		....	615	453	W.S.W. to W.	104	102	103	3			Cap over pipe with 8-in. flange gave downdraught at 9 in. below top of pipe when tried in position A at 60°, and in position B at 30°; similarly at 6 in. below top of pipe in position B at 40°, but at 4 in. below top of pipe no downdraught was observed.
	23 Apl., '95	73b			533	360	From S.S.W. to S.W. by W.	114	111	113	4	......	B 50°	
XXIX.	23 Feb., '88	74		....	624	515	From E.N.E. to E.	107	105	106	3	......*	See Remarks.	*As the Raingauge cap without flange gave a bad result when placed on sloping roof and particularly when wind blew at right angles to ridge, a flange was fixed to the pipe and improved the general efficiency.
XXXIX.	7 Sep., '87	75		....	430	138	W.N.W.	90	85	87	3	.....	B 20°	**73a.** As the addition of a plate considerably decreased the upcast efficiency of the terminal, a closed cone was substituted. **74.** See also fig. H, p. 399. No downdraught observed.
XXXIX.	17 Aug., '87	76		......x = 1½″	221	218	E.N.E.	75	74	75	3			**75.** For experiments without cap see Sketch No. 16A, p. 350.
XXXIX.	17 Aug., '87			...... x = 3″	232	184	E.N.E. by N. to E.N.E.	79	75	77	4			

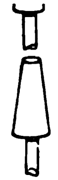
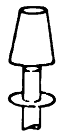
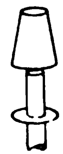
Sheet.	Date.	Sketch of Terminal.		Velocity of Cups, feet per minute Max.	Min	Direction of Wind.	Efficiency. Max.	Min.	Average	Number of Experiments.	Reference Letters.	Angle from vertical at which downdraught is observed.	Remarks.
												A = down-blow. B = up-blow.	
LX.	16 Apr., '95	77 	... a	508	420	From E. by N. to E. by S.	120	113	117	5	......	....	See General Notes *re* square types. For similar terminal in circular form see fig. B J, p. 416. The 9-in. square raingauge cap was tested for downdraught above a square pipe 9 inches long only, and showed downdraught in position B at 30°. The length of the square pipe, however, appears to be immaterial.
LX.	16 Apr., '95		... b	556	427	From E. by N. to E. by S.	114	109	111	3			
XXXIX.	28 Oct., '87	78 	... a	417	284	From W. to W.N.W.	132	125	129	3	......	....	See Remarks to Sketch No. 77.
XXXIX.	28 Oct., '87		... b	357	316	W.	119	116	118	3			
XXXIX.	28 Oct., '87	79 Same as above but Cap 3 inches above pipe.	... a	350	350	W.	125	125	125	1	......	....	See Remarks to Sketch No. 77.
XXXIX.	28 Oct., '87		... b	288	266	From W. to W.N.W.	123	119	121	2			
XXXV.	28 Jan., '88 2 Apr., '88	80 	... a	578	342	From W.N.W. to N.N.W.	116	109	113	6	......	See Remarks.	See General Notes *re* square types. For similar terminal in circular form see Sketch No. 73, p. 359, and fig. O, p. 400. No downdraught observed.
XXXV.	28 Jan., '88 2 Apr., '88		... b	520	385	From W.N.W. to N.W.	117	108	112	6			
XXXV.	2 Apr., '88	81 	... a	580	308	From N. to N.N.W.	113	109	111	3	......	B 40°	See General Notes *re* square types. For similar terminal in circular form see Sketch No. 73, p. 359, and fig. O, p. 400.

XXXV.	16 Jan., '88	82a		.... a	580	490	E.N.E.	116	114	115	2	......	....	For similar terminal in circular form, see Sketch No. 73, p. 359, fig. O, p. 400. See General Notes *re* square types.
XXXV.	16 Jan., '88			.... b	523	392	E.N.E.	115	113	114	3			
LVI.[G.]	7 Feb., '98	83		....	737	353	From W.N.W. to N.W.	129	126	128	3			
LVI.[G.]	7 Feb., '98	84		... $x = 1''$	498	430	From W.N.W. to N.W.	132	127	130	3	......	....	See General Notes *re* square types. x = distance between top edge of pipe and lower edge of cap.
LVI.[G.]	7 Feb., '98			... $x = 2''$	432	405	From W.N.W. to N.W.	135	134	134	3			
XXXVII.	28 Oct., '87	85		.... a	314	246	W.N.W.	115	115	115	2	......	B 40°	See General Notes *re* square types. Compare with Sketch No. 116.
XXXVII.	28 Oct., '87			.... b	377	352	W.N.W.	114	112	113	2			
LXI.	13 Apr., '95 7 Aug., '95 12 Aug., '95	86		....	629	148	From E. to S.W. by W.	129	111	122	10	......	B 30°	For caps of various sizes at different distances above diverging tubes see special table, also fig AG, p. 407. General average of 13 experiments with outside stays 121. General average of 27 experiments with inside stays 123.
LXIII.	4 May, '95	87		... $x = 5''$	611	480	From N.E. by E. to E.N.E.	123	118	121	5	......	See Remarks.	See Remarks to sketch No. 73. No downdraught observed when tested with cap 1 inch above (not 1½ inches as tested for exhaust). Same terminal with 10-in. flange 6 inches down was downdraught proof.
LXIII.	1 May, '95			... $x = 6''$	674	571	From S.W. to W.S.W.	120	117	118	5		B 30°	

Sheet.	Date.	Sketch of Terminal.		Velocity of Cups, feet per minute.		Direction of Wind.	Efficiency.			Number of Experiments.	Reference Letters.	Angle from vertical at which downdraught is observed.	Remarks.
				Max.	Min.		Max.	Min.	Average.				
												A = down-blow. B = up-blow.	
LXIII.	31 Aug., '95	88 	......	362	292	From W.S.W. to N.W.	121	119	120	3	......	See Remarks.	See Remarks to Sketch No. 73. No downdraught observed.
LXIII.	4 May, '95	89 	$x = 5''$	508	402	From N.N.E. to E.	127	122	125	8	......	See Remarks.	See Remarks to Sketch No. 73A. No downdraught observed.
LXIII.	30 Apr., '95		$x = 6''$	400	236	From S.W. by S. to W.S.W.	126	123	125	5	......	B 30°	Similar Terminal with top of conical drum increased to 10 inches was downdraught-proof.
LXIII.	31 Aug., '95	90 	....	342	319	From W.N.W. by N.W.	129	124	127	3	DB*	See Remarks.	See Remarks to Sketch No. 73A. No downdraught observed. *DB Tests with 13-in. cap and 13-in. × 18-in. similar closed cone.
LXIX.	18 June, '95	91 	......	234	204	From S.S.W. to N.N.W.	136	129	132	5	......	See Remarks.	See Remarks to Sketch No. 73. No downdraught observed. See also fig. A F, p. 406 (without flange).
LXXXIII.	15 July, '96 [illegible]		.... a	460	221	From N.E. to W. by N.	107	95	101	6	......	A 60°	This is a Sugarloaf purchased in the ordinary course from the trade. As shown on sketch the pipe is inserted [illegible] into the Sugarloaf, and

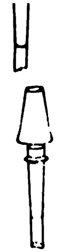
	ar. '98			.... a	580	490	E.N.E.	116	114	115	2	......	....	For similar terminal in circular form, see Sketch No. 73, p. 359, fig. O, p. 400. See General Notes *re* square types.
	an., '88	82a		.... b	523	392	E.N.E.	115	113	114	3			
	b., '98	83		....	737	353	From W.N.W. to N.W.	129	126	128	3			
	b., '98	84		... $x = 1''$	498	430	From W.N.W. to N.W.	132	127	130	3	......	....	See General Notes *re* square types. x = distance between top edge of pipe and lower edge of cap.
	'98			... $x = 2''$	432	405	From W.N.W. to N.W.	135	134	134	3			
	28 Oct., '87	85		.... a	314	246	W.N.W.	115	115	115	2	......	B 40°	See General Notes *re* square types. Compare with Sketch No. 116.
	Oct., '87			.... b	377	352	W.N.W.	114	112	113	2			
LXI.	13 Apr., '95 7 Aug., '95 12 Aug., '95	86		....	629	148	From E. to S.W. by W.	129	111	122	10	......	B 30°	For caps of various sizes at different distances above diverging tubes see special table, also fig. AG, p. 407. General average of 13 experiments with outside stays 121. General average of 27 experiments with inside stays 123.
LXIII.	4 May, '95	87		... $x = 5''$	611	480	From N.E. by E. to E.N.E.	123	118	121	5	......	See Remarks.	See Remarks to sketch No. 73. No downdraught observed when tested with cap 1 inch above (not $1\frac{1}{2}$ inches as tested for exhaust). Same terminal with 10-in. flange 6 inches down was downdraught proof.
LXIII.	1 May, '95			... $x = 6''$	674	571	From S.W. to W.S.W.	120	117	118	5		B 30°	

Sheet.	Date.	Sketch of Terminal.		Velocity of Cups, feet per minute. Max.	Min.	Direction of Wind.	Efficiency. Max.	Min.	Average.	Number of Experiments.	Reference Letters.	Angle from vertical at which downdraught is observed.	Remarks.
												A = down-blow. B = up-blow.	
LXXXIV.	4 Aug., '96	99 	...... *a*	402	297	From W.N.W. to N.N.W.	103	100	102	4	S	B 50°	
LXXXIV.	4 Aug., '96		...... *b*	425	312	N.W.	98	96	97	3			
LXXXIV.	4 Aug., '96	100 	....	362	239	From N.W. by W. to N.N.W.	119	106	112	4	S	B 40°	See also fig. A J, p. 409. Similar terminal but with Sugarloaf 1½ ins. above pipe gave downdraught when tried in position *b* at 30°, 2 ins. above pipe in position *b* at 40°, 3 ins. above in position at 40°, and 4 ins. above in position *b* at 50°.
LXXXIV.	30 Nov., '96	101 	...... *a*	244	206	From E. to E.S.E.	99	97	98	3	S		
LXXXIV.	30 Nov., '96		...... *b*	349	251	From E. to E.S.E.	92	91	92	3			
LXXXIV.	30 Nov., '96	102 	...... *a*	279	219	E.	116	114	115	3	D B R* S	B 30°	See also fig. A J, p. 409. This terminal was also tried for downdraught with pipe inserted into Sugarloaf various distances producing the following effects: Insertion 1½ ins. gave downdraught in position *b* at 30°, 2¼ ins. in position *b* at 40°, 3 ins. in position *a* at 60° and *b* at 40°, 4½ ins. in position *a* at 60° and *b* at 50°.
LXXXV.	22 July, '96	103 	....	458	407	From W. by S. to N.W.	117	114	116	4	.....	B 30°	* For sloping roof results see fig. B X, p. 421. 103.—Similar terminal with four feathers gave downdraught in position *b* at 40°.
LXXXVI.	4 Aug., '96 11 Aug., '96	104 	.. ..	390	266	From W. to N. by W.	110	101	106	7	DB*	B 40°	Similar terminal to Sketch No. 103

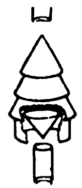
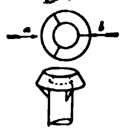
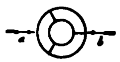
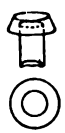
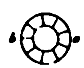
LXXXVII.	24 Sep., '96	107		…………	284	220	From S.W. by S. to W.S.W.	127	121	124	3	……	B 30°	Terminal gave downdraught when tried in position b at 40°, and with pipe flush or $1\frac{1}{2}$ below cylinder in position b at 30°. See diagram. 
LXXXVII.	11 Aug., '96	108		…………	319	231	From W. to N. by W.	103	102	102	3	R*	See Remarks.	No downdraught observed. Similar Terminal, but with 12-in. flange 9 in. down pipe gave downdraught when tried in position a at 60°; 12 in. down pipe was downdraught-proof; and 15 in. down pipe gave downdraught in position b at 50°. * With Flange 9″ diameter this Terminal was tried in wind directions from W. to N.W. (see Sketch No. 204) and gave better upcast results than those shown on fig. BX, p. 421.
LXXXVII.	19 Mar., '97	109		…………	787	720	From W.S.W. to W. by N.	108	105	107	3	……	See Remarks.	109. No downdraught observed. With Flange 8 in. below orifice downdraught was observed in position b at 40°. See also Remarks to Sketch No. 73.
LXXXVIII.	26 Oct., '96	110		$x=2''$	161	126	From S.W. to W.S.W.	119	114	117	2	R*	See Remarks.	110. As the addition of a Flange greatly diminished the efficiency, a small fillet, which was found not to diminish the upcast and yet afford protection against downdraught, was substituted. No downdraught observed.
LXXXVIII.	19 Mar., '97			$x=3''$	774	651	From W.S.W. to W.	114	111	113	3	……	B 50°	Similar Terminal, but Sugarloaf enlarged to 9 in. at bottom and $13\frac{1}{4}$ in. side, with fillet $6\frac{11}{16}$ in., was downdraught-proof at $4\frac{1}{2}$ in. down, but when fixed 6 in. down showed downdraught in position b at 40°. With 1-in. astragal substituted for fillet 3 in. down the pipe the terminal became downdraught-proof, but at $4\frac{1}{2}$ in. down showed downdraught when tried in position b at 40°. * Only a few Sloping-roof tests were made, with results practically the same as those of the Terminal without fillet when tried on Sloping roof.
LXXXVIII.	15 Feb., '98	111		…………	646	629	From W.S.W. to W.	91	89	90	2	……	………………	111. These experiments were made to compare with those shown at Sketch No. 10, but apparently the addition of the Sugarloaf decreased the upcast efficiency.

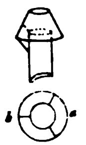
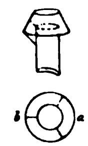
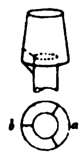
Sheet.	Date.	Sketch of Terminal.		Velocity of Cups, feet per minute.		Direction of Wind.	Efficiency.			Number of Experiments.	Reference Letters.	Angle from vertical at which downdraught is observed.	Remarks.
				Max.	Min.		Max.	Min.	Average.				
LXXXVIII.	26 Oct., '96	112		410	349	From S.W. to S.W. by W.	126	125	126	3	.....	A = down-blow. B = up-blow. See Remarks.	This ring was fitted near orifice of the diverging tube to prevent downdraught from deflected wind, and does not diminish the upcast efficiency. No downdraught observed. Similar terminal but Sugar-loaf 4 in. top, 9¼ in. side, gave downdraught when tried in position B at 60°. When the size of the Sugar-loaf was increased to 4½ ins. at top and 18 ins. side the same downdraught result obtained. Downdraught experiments were also tried with Sugar-loaves of various sizes over a 4½ in. × 8 in. diverging tube similar to diagram No. 45. For brevity these have been marked 45A to 45F. The results are given in the table below:—

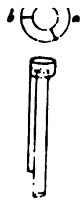
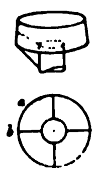
No. of Sugar-loaf.	Top.	Bottom.	Side.	Distance from diverging tube.	Angle at which downdraught was shown in positions A & B.	
					A	B
45A	4½	9	18	1⅛ above	...	30°
45B	4	7½	9⅝	1⅛ ,,	...	50°
45C	4½	7½	9	½ ,,	60°	50°
,,	,,	,,	,,	1⅛ ,,	60°	40°
,,	,,	,,	,,	1¾ ,,	60°	40°
,,	,,	,,	,,	3 ,,	60°	30°
,,	,,	,,	,,	3½ ,,	60°	50°
,,	,,	,,	,,	4 ,,	50°	50°
45D	4½	7½	9	3 inserted	40°	60°

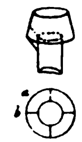
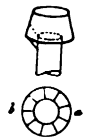
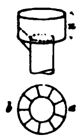
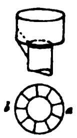
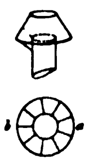
LXXXVIII.	27 Feb., '97	114		....	231	121	From N.W. to N.N.W.	134	131	132	3	......	See Remarks.	...not diminish the upcast efficiency. No downdraught observed. As the maintenance of a definite ratio between the annular space at bottom of Sugarloaf to that at top was imperative, a fillet of larger diameter was required upon the diverging tube in this case to protect the terminal from downdraught from deflected wind. No downdraught observed. With fillet 4½ in. below orifice, downdraught was observed in position B at 40°.
LXXXIX.	13 Aug., '96	115		....	400	297	From W.S.W. to W.N.W.	114	106	110	3	......	....	114. Similar Sugarloaf, 4½-in. top, 7½-in. bottom, and 9-in. side, with 5-in. fillet 3 in. down, gave downdraught when tried in position B at 40°.
LXXXIX.	12 Aug., '96	116		$x=1''$	241	189	From W.N.W. to N.N.W.	112	110	111	3	......	....	115. Similar to terminal shown at Sketch No. 104, but plate added as a protection against rain.
LXXXIX.	12 Aug., '96			$x=1\frac{1}{2}''$	221	163	N.W.	116	113	114	3	......	B 30°	This terminal was also tried in the year 1887, and gave an upcast efficiency of 112.
LXXXIX.	12 Aug., '96	117		....	332	259	From W.N.W. to N.N.W.	111	109	110	3	......	B 30°	This terminal was also tried in the year 1887, and gave an upcast efficiency of 109.
XCI.	13 Aug., '96	118		....	333	269	From W.S.W. to W.	116	112	114	3	......	....	Similar to terminal shown at Sketch No. 104, but surmounted by Rain-gauge Cap to accelerate the upcast. See also fig. A N, p. 410.
XCI.	13 Aug., '96	119		$x=1\frac{1}{2}''$	485	430	From W. to W.N.W.	121	116	118	3			
XCI.	13 Aug., '96			$x=2\frac{1}{2}''$	563	427	From W. by S. to W. by N.	120	117	119	3			

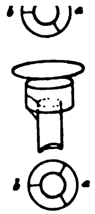
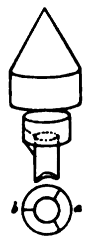
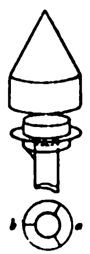
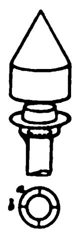
[illegible]	Date.	Sketch of Terminal.			Velocity of Cups, feet per minute.		Direction of Wind.	Efficiency.			Number of Experiments.	Reference Letters.	Angle from vertical at which downdraught is observed.	Remarks.
					Max.	Min.		Max.	Min.	Average.			A = down-blow. B = up-blow.	
XC.	11 Aug., '96	120		... $x = 1''$ ... $z = 1''$	279	168	From W.N.W. to N.W.	118	112	116	3			
XC.	12 Aug., '96			... $x = 1''$ ... $z = 1\frac{1}{2}''$	206	158	From N.W. to N.	116	115	116	3			
XC.	12 Aug., '96			... $x = 1\frac{1}{2}''$ ... $z = 1\frac{1}{2}''$	324	116	From W.N.W. to N.W.	120	116	118	3	......	B 40°	
XC.	5 July, '97 7 July, '97	121		....	611	302	From S.W. to N.W.	119	111	114	6	......	....	Fillet added to render terminal proof against downdraught from deflected winds. No downdraught observed.
XCI.	7 July, '97	122		....	347	322	From W to N.W.	123	120	121	3			
XCI.	7 July, '97	123		....	402	352	From W. to N.W.	123	118	121	3	......	....	See remarks to Sketch No. 121.
LXXXVIII.	27 Feb., '97	124		....	128	118	From N.W. to N.N.W.	135	133	134	3	......	....	No downdraught observed. See also fig. A O, p. 410, and remarks to Sketch No. 121.

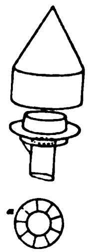
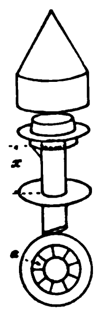
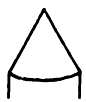
XL.	2 Aug., '87	126		....	342	178	N.N.W.	114	112	113	3	......	B 20°	**126.** The cone was inserted with the object of preventing downdraught from deflected winds, but results show that the cone does not have the desired effect. Same terminal with cone removed gave downdraught when tried in position B at 50°. Same terminal but with elongated cone inserted gave downdraught when tried in position B at 50°, and with 7 in. open cylinder inserted gave downdraught at the same angle. See also fig. B P, p. 417.
XXI^B.	21 July, '96	127		...... *a*	339	277	From S.W. by S. to S.W. by W.	78	70	76	3			
XXI^B.	21 July, '96			...... *b*	387	272	From S.W. to W.S.W.	54	50	52	3			
XXI^B.	21 July, '96	128		...... *a*	480	306	From S.W. by S. to W.S.W.	117	113	115*	3	......	A 40°	* General average of 18 experiments is 114. See also fig. B O, p. 417.
XCIV*.														
XXI^B.	21 July, '96			...... *b*	394	237	From S.W. to W. by S.	109	106	107*	3			
XCII.	27 Jan., '97 15 Feb., '97	129		....	343	156	From N.E. to N.W.	98	92	96	6	......	....	This louvre, which is supported by wires, compares with that shown at Sketch No. 128, which has feather attachments. When attached with three feathers general average of 18 experiments is 114.
XCII.	7 Jan., '98	130		....	319	224	From W.N.W. to N.W.	106	101	103	3	S	....	This louvre, which is supported by wires, compares with that shown at Sketch No. 131, which has feather attachments.
XCII.	7 Jan., '98	131		...... *a*	312	302	„ N.W. by W. to N.W. by N.	131	126	129*	2	S	....	* General average of 17 experiments is 127. For effect of feathers without louvre attached see Sketch No. 8.
CIV.														
XCII.	7 Jan., '98			...... *b*	369	264	N.W.	130	125	128*	2			

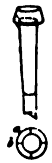
Sheet	Date		Sketch of Terminal		Velocity of Cups, feet per minute. Max.	Min	Direction of Wind.	Efficiency. Max.	Min.	Average.	Number of Experiments.	Reference Letters.	Angle from vertical at which downdraught is observed.	Remarks.
													A = down-blow. B = up-blow.	
XCIII.	22 Feb., '97 24 Feb., '97	132		.... a	491	221	From S.W. to W.N.W.	113	106	110	6	......	B 40°	
XCIII.	22 Feb., '97 24 Feb., '97			.... b	478	357	From S.W. to W.N.W.	77	70	75	6			
XCIII.	22 Feb., '97	133		.... a	380	287	From W. by S. by W.N.W.	119	113	115	3	......	A 50°	Similar terminal, 3 in. deep, with three- and four-feather attachment, gave downdraught both in position A and in position B at 60°.
XCIII.	22 Feb., '97			.... b	320	241	From W. by S. to N.W. by W.	101	89	94	4			
XCIV.	15 Feb., '97 22 Feb., '97 24 Feb., '97	134		.... a	568	133	From E. to W.N.W.	127	115	121	9	S*	A 40°	* Smoke tests also made with 4, 5, and 7 feathers. Special smoke test also made with 4 feathers, thus:— 
XCIV.	15 Feb., '97 22 Feb., '97 24 Feb., '97			.... b	661	146	From E. to W. by N.	111	104	107	9			
XCIV.	15 Feb., '94	135		.... a	211	166	From E. to S.E.	119	113	115	3			
XCIV.	15 Feb., '94			.... b	173	153	From E. to S.E.	108	104	106	3			
XCV.	24 & 26 Feb., '97 4, 9, 10, & 12 Mar., '97	186		.... a	890	304	From S.S.E. to W.	128	123	125	15	......	A 30°	See also fig. B E, p. 415.
XCV.	24 & 26 Feb., '97 4, 9, 10, & 11 Mar., '97			.... b	797	211	From S.S.E. to W.	120	112	116	15			

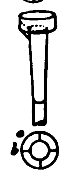
XCVI.	4 Mar., '97	139		...... a	840	490	From S.W. by S. to S.W.	124	121	123	3	.....	....	Similar to terminal shown at Sketch No. 136, but feathers carried down pipe to ascertain whether this would increase the efficiency.
XCVI.	4 Mar., '97			...... b	646	593	S.W.	110	106	108	3			
XCIX.	26 Mar., '97	140		...... a	980	770	S.W. by S.	125	121	123	2	......	....	See also fig. A S, p. 412.
XCIX.	26 Mar., '97			...... b	835	747	From S.S.W. to S.W.	119	115	117	2			
C.	24 Mar., '97 30 Apl., '97	141		...... a	978	337	From S.W. to W. by N.	116	115	116	3			
C.	24 Mar., '97 30 Apl., '97			...... b	913	556	From S.W. to W.	112	108	110	3			
C.	30 Apl., '97	142		...... a	450	442	From S.W. by S. to S.W.	113	111	112	2	......	A 60° B 60°	Similar terminal with three feathers showed downdraught when tried both in position A and in position B at 60°.
C.	30 Apl., '97			...... b	548	530	S.W.	98	97	98	2			
CIII.	21 May, '97	143		...... a	626	623	From N.E. by E. to E.	125	125	125	2	......	....	See also fig. A S, p. 412.
CIII.	21 May, '97			...... b	770	525	From N.E. by E. to E.	130	130	130	2			
CIII.	26 Mar., '97	144		...... a	815	807	S.W.	117	116	117	2	......	....	See also fig. A S, p. 412.
CIII.	26 Mar., '97			...... b	897	747	S.W.	121	119	120	2			

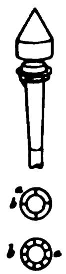
Sheet.	Date	Sketch of Terminal.		Velocity of Cups, feet per minute. Max.	Min	Direction of Wind.	Efficiency. Max.	Min.	Average.	Number of Experiments.	Reference Letters.	Angle from vertical at which downdraught is observed.	Remarks.
												A = down-blow. B = up-blow.	
CI.	23 Mar., '97 24 Mar., '97	145 	.... a	938	264	From S.S.W. to W. by N.	126	117	122	4	......	A 40°	See also fig. A T, p. 412.
CI.	23 Mar., '97 24 Mar., '97		.... b	955	254	From S.S.W. to W. by N.	121	111	117	3			Similar terminal with $2\frac{1}{4}$-in. top gave downdraught when tried in position B at 50°.
CIV.	10 Nov., '97 29 Nov., '97	146 	.... a	480	189	From E. by N. to N.W.	129	116	122	4	......	....	Compare with terminal shown at Sketch No. 145.
CIV.	10 Nov., '97 29 Nov., '97		.... b	468	138	From E.S.E. to N.W.	130	117	125	4			
CV.	10 Nov., '97 29 Nov., '97 15 Feb., '98	147 	.... a	591	116	From E. by N. to N.W.	124	119	122	6	......	....	See also fig. A Q, p. 412, with $x=3''$.
CV.	10 Nov., '97 29 Nov., '97 15 Feb., '98		.... b	576	113	From E. by N. to N.W.	124	116	121	6			
CV.	15 Feb., '93	148 	.... a	541	503	From S.W. to W.S.W.	120	117	119	2	......	....	This terminal compares with that shown at Sketch No. 147, and on fig. BF, p. 415, with $x=\frac{1}{2}''$ below louvre.
CV.	15 Feb., '98		.... b	644	601	From S.W. to W.S.W.	119	116	118	2			
CV.	3 Nov., '97	149 	.... a	453	390	From N.E. by E. to E.N.E.	114	114	114	2	S* DB	....	*Smoke test also made with 4 feathers to louvre.
CV.	3 Nov., '97		.... b	415	402	From N.E. by E. to E.N.E.	121	120	121	2			This construction was designed as a downdraught-proof, coverless terminal, but was not subjected to practical downdraught test. Provisional Patent Number 16735.

														1¼ in. over a 3-in. pipe fixed with wires, gave downdraught when tested in position B at 30°.
CXIV.	26 Feb., '97	152		...... *a*	704	671	W.S.W.	123	121	122	3	......	B 50°	
CXIV.	26 Feb., '97			...... *b*	651	563	W.S.W.	110	106	108	3			
CXIV.	26 Feb., '97	153		...... *a*	669	447	From S.W. to W.S.W.	130	128	129	3	......	B 30°	Similar to terminal shown at Sketch No. 151, but rain guage cap substituted for plate.
CXIV.	26 Feb., '97			...... *b*	634	603	S.W. by W.	122	120	121	3			
CXIV.	26 Feb., '97	154		...... *a*	606	460	From S.S.W. to S.W.	130	126	128	3	......	....	The flange was fixed around the louvre to prevent downdraught from deflected winds. Similar terminal with 7½-in. flange around the louvre gave downdraught when tried in position B at 30°. No downdraught observed. See also fig. A X, p. 413.
CXIV.	26 Feb., '97			...... *b*	651	591	From S.S.W. to S.W.	119	117	118	3			
CXV.	5 July, '97 7 Aug., '97 12 Oct., '97 22 Oct., '97	155		...... *a*	772	186	From E.N.E. to N.N.W.	128	118	124	9	D B	....	See also fig. B A, p. 414.
CXV.	5 July, '97 7 Aug., '97 12 Oct., '97 22 Oct., '97			.. ... *b*	732	264	From N.E. by E. to W.	118	111	113	7			

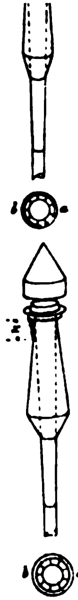
Sheet.	Date.	Sketch of Terminal.		Velocity of Cups, feet per minute. Max.	Min.	Direction of Wind.	Efficiency. Max.	Min.	Average.	Number of Experiments.	Reference Letters.	Angle from vertical at which downdraught is observed.	Remarks.
CXXI.	5 Feb., '98	156 	.... a	405	317	From N.W. by N. to N. by W.	134	133	134	3	D B R*	....	See also figs. A Z and B B, p. 414, on the latter of which the general average of 30 experiments appears as 133. The Committee considered this both the most compact and the most effective terminal to a 3-in. pipe (see Part 5, p. 395). A smaller specimen of the same type is shown at Sketch No. 155, and fig. B A, p. 414. * For sloping roof results see Part 5, pp. 338 & 421, also fig. B Z, p. 421. The same design was applied to diverging tubes and gave a rather higher efficiency (see No. 174 & 179). Provisional Patent Number 16735.
CXXI.	5 Feb., '98	157 	$x = 3''$	360	299	From N.W. to N.N.W.	119	117	118	3	R	....	The results when this terminal was fixed on sloping roof were better than those of the same terminal without flange, the upcast efficiency with wind directly at right angles to ridge being nearly 30 per cent. in excess, but at an angle of 45°, the results of the two terminals nearly coincide (see Sketch No. 296, p. 444).
CXXI.	5 Feb., '98		$x = 6''$	367	294	From N.N.W. to N. by W.	118	115	116	3			
CXXII.	2 Nov., '97		$x = 12''$	307	277	From N.W. to N.N.W.	124	123	123	3			
CXXII.	2 Nov., '97												
			.... a $x = \frac{3}{4}''$	324	307	From E.N.E. to E.	134	132	133	2			
CXXII.	2 Nov., '97		.... b $x = \frac{3}{4}''$	229	209	From E.N.E. to E. by N.	133	130	132	2			
CXXII.	2 Nov., '97		.... a $x = 1\frac{1}{2}''$	385	377	From E.N.E. to E.	136	133	135*	2	......	....	* See also Sketch No. 156, and figs. A Z and B B, p. 414.

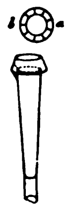
CXXII.	3 Nov., '97			$x=\frac{3}{4}$ .... b	427	387	From N.E. to E.N.E.	136	135	136	2			
CXXII.	3 Nov., '97			$x=\frac{3}{4}''$ .... a	432	415	From N.E. by N. to E.N.E.	134	133	134*	2	......	....	* See also Sketches Nos. 156 & 158 and figs. A Z and B B, p. 414.
CXXII.	3 Nov., '97			$x=1\frac{1}{4}''$ ... . b	435	357	From N.E. by N. to E.N.E.	137	134	136*	2			
CXXII.	3 Nov., '97			$x=1\frac{1}{4}''$ . ... a	440	397	From N.E. to E.N.E.	136	132	134	2			
CXXII.	3 Nov., '97			$x=3''$ .... b $x=3''$	470	407	From N.E. to E.N.E.	136	132	134	2			
CVI.	16 Sep., '97 21 Sep., '97	160		....	392	151	From W.N.W. to N.N.W.	114	107	111	6	S	....	This terminal, which was fitted with wires, compares with that shown at Sketch No. 161, which has feather attachment. For results of experiments upon plain diverging tube $4\frac{1}{2} \times 18$ ins. see fig. B R, p. 418.
CVI.	16 Sep., '97 21 Sep., '97	161		.... a	312	128	From W.N.W. to N.N.W.	130	124	132	4	S	....	See also fig. A U, p. 413.
CVI.	16 Sep., '97 21 Sep., '97			.... b	402	118	From W.N.W. to N.W. by N.	130	128	133	5			
CVI.	9 July, '97	162		.... a	314	302	From S.W. by S. to W. by N.	128	127	128	2	......	....	See also fig. A U, p. 413.
CVI.	9 July, '97			.... b	362	274	From S.W. by N.W.	119	117	118	3			
CVI.	9 July, '97	163		.... a	400	354	From W.S.W. to W.	133	128	131	2	......	....	See also fig. A U, p. 413.
CVI.	9 July, '97			.... b	455	435	From W.S.W. to W.N.W.	132	131	132	2			
CVII.	26 Mar., '97	164		.... a	709	681	From S.S.W. to S.W.	130	130	130	2			
CVII.	26 Mar., '97			.... b	802	747	From S.S.W. to S.W.	124	123	124	2			

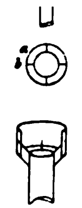
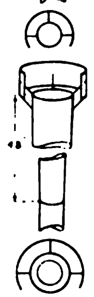
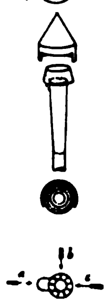
Sheet.	Date.	Sketch of Terminal.		Velocity of Cups, feet per minute. Max.	Min.	Direction of Wind.	Efficiency. Max.	Min.	Average.	Number of Experiments.	Reference Letters.	Angle from vertical at which downdraught is observed.	Remarks.
CVII.	24 Mar., '97	165 	.... a	629	626	From W.S.W. to W. by N.	131	127	129	2			
CVII.	26 Mar., '97		.... b	724	679	From W.S.W. to W. by N.	131	128	130	2			
CIX.	19 June, '97 3 July, '97 13 July, '97	166 	.... a	716	490	From E.N.E. to N.W.	144	134	138	6	......	....	See also fig. AU, p. 413.
CIX.	19 June, '97 3 July, '97 13 July, '97		.. . . b	757	430	From E.N.E. to N.W.	144	135	141	6			
CIX.	26 Mar., '97 19 June, '97	167 	.... a	749	530	From S.W. to N.W.	136	131	133	4			
CIX.	26 Mar., '97 19 June, '97		.... b	827	505	From S.W. by S. to N.W. by N.	140	136	137	4			
CX.	19 June, '97	168 	... . a	503	445	From W.N.W. to N.W.	137	135	136	2			
CX.	19 June, '97		.... b	478	478	W.N.W.	140	139	140	2			
CX.	19 June, '97	169 	.... a	425	415	From W. to N.N.W.	138	132	135	2			
CX.	19 June, '97		.... b	427	387	W.N.W.	136	136	136	2			

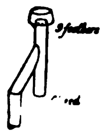
CXIII.	12 Aug., '97	172		.... a	437	422	From W.S.W. to W.N.W.	133	133	133	2			at sketches Nos. 172 and 173 tried on the same days.
CXIII.	12 Aug., '97			.... b	623	453	From W.S.W. to W.N.W.	137	132	135	2			
CXIII.	12 Aug., '97	173		.... a	468	442	From W. to W.N.W.	127	128	127	2	......	....	In the early stages of the investigation of the working of louvre terminals, the Committee were uncertain as to the direction taken by the wind after it struck the diverging tube. This terminal was therefore constructed with the object of driving the current of air which struck the upper part of the double cone, enveloping the diverging tube into the pocket or pockets formed by the feather attachment. Further experiments were made by adding Rainguage Caps to similar terminals of larger dimensions, as shown at sketches Nos. 180 and 181.
CXIII.	12 Aug., '97			.... b	450	377	From W. to W.N.W.	130	130	130	2			
CXXIV.	2 Feb., '98	174		.... a	857	827	W.	137	136	137	2	......	....	See also fig. BC., p. 414. General average of 20 experiments is 130. This cone and cap is similar to 156.
CXXIV.	2 Feb., '98			.... b	850	822	W.	137	134	136	2			
CXXIV.	2 Feb., '98			.... a	998	915	W.	143	142	143	2			
CXXIV.	2 Feb., '98			.... b	1056	1046	W.	144	142	143	2			
CXXV.	4 Aug., '97	175		.... a	422	251	S.E.	140	133	137	2			
CXXV.	4 Aug., '97			.... b	337	327	S.E.	137	135	136	2			

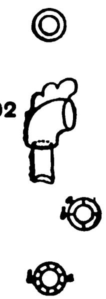
Sheet.	Date.	Sketch of Terminal.	Velocity of Cups, feet per minute. Max.	Velocity of Cups, feet per minute. Min.	Direction of Wind.	Efficiency. Max.	Efficiency. Min.	Efficiency. Average.	Number of Experiments.	Reference Letters.	Angle from vertical at which downdraught is observed.	Remarks.
CXXV.	19 June, '97	176  a ... $x=1\frac{1}{2}''$	284	282	From W. to N.W.	138	137	138	2			
CXXV.	19 June, '97	b ... $x=1\frac{1}{2}''$	493	442	From W. by S. to N.W. by W.	134	129	132	2			
CXXV.	19 June, '97	a ... $x=2\frac{9}{16}''$	473	294	From W. by S. to W. by N.	140	134	137	2			
CXXV.	19 June, '97	b ... $x=2\frac{9}{16}''$	420	392	From W. by S. to W. by N.	138	137	138	2			
CXXV.	15 June, '97	177  .... a	344	337	S.W.	133	133	133	2			
CXXV.	15 June, '97	.... b	347	282	S.W.	132	130	131	2			
CX.	16 Sep., '97 17 Sep., '97 4 Oct., '97 8 Oct., '97	178  .... b	367	168	From S.W. by S. to N.W.	149	137	142	8	......	....	For plain diverging tube 5" × 48", see fig. B R, p. 418. See also fig. A W, p. 413.
CX.	16 Sep., '97 17 Sep., '97 4 Oct., '97 8 Oct., '97	.... b	322	126	From S.W. to N.W.	149	138	144	8			
CXXIX.	21 Oct., '97	179  .... a	390	297	From N.E. to E.	159	151	155	2	S*	....	General average of 28 experiments is 153. * Smoke test made with 11 feathers to louvre as well as with 9 feathers. See also fig. B D, p. 414. This cone and cap is similar to 156.
CXXIX.	21 Oct., '97	.... b	309	294	From E.N.E. to E.	154	152	153	2			

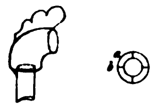
CXXIX.	21 Oct., '97	181		...$x=1\frac{3}{4}''$ a	392	294	From E.N.E. to E.	138	136	137	2	.....	....	See remarks to Sketch No. 173.
CXXIX.	21 Oct., '97			.. $x=1\frac{3}{4}''$ b	297	256	From N.E. to E.	136	136	136	2			
CXXIX.	21 Oct., '97			...$x=5\frac{1}{2}''$ a	329	231	From E.N.E. to E.	136	132	134	2			
CXXIX.	21 Oct., '97			...$x=5\frac{1}{2}''$ b	289	231	From E.N.E. to E. by S.	136	135	136	2			
CXXX.	23 Oct., '97	182		...$x=1\frac{3}{4}''$ a	503	470	From E.N.E. to E.	155	154	155*	2	.....	....	* See also Sketch No. 179 and fig. B D, p. 414. x = the length of the feather below the conical ring.
CXXX.	23 Oct., '97			...$x=1\frac{3}{4}''$ b	608	329	From E.N.E. to E.	156	156	156*	2			
CXXX.	23 Oct., '97			... $x=5''$ a	722	458	From E.N.E. to E.	154	153	154	2			
CXXX.	23 Oct., '97			... $x=5''$ b	470	453	From E.N.E. to E.	152	152	152	2			
CXXX.	23 Oct., '97			... $x=9''$ a	611	591	From E.N.E. to E.	141	139	140	2			
CXXX.	23 Oct., '94			... $x=9''$ b	634	385	From E.N.E. to E.	148	142	145	2			

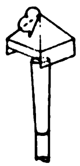
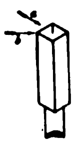
Sheet.	Date.	Sketch of Terminal.			Velocity of Cups, feet per minute.		Direction of Wind.	Efficiency.			Number of Experiments.	Reference Letters.	Angle from vertical at which downdraught is observed.	Remarks.
					Max.	Min.		Max.	Min.	Average.				
CXXX.	4 Nov., '97	183		.... *a* $x=\frac{3}{4}''$	244	244	From N.N.E. to N.E.	...	..	152	1			
CXXX.	4 Nov., '97			.... *a* $x=1\frac{1}{2}''$	251	221	From N.N.E. to N.E.	155	149	152	2			
CXXX.	4 Nov., '97			.... *b* $x=1\frac{1}{2}''$	289	206	From N.E. by N. to N.E.	153	152	153	2			
CXXX.	4 Nov., '97			.... *a* $x=3''$	251	209	From N.N.E. to N.E.	153	151	152*	2	....	....	* See also Sketches Nos. 179, 182, and fig. B D, p. 414. x = the height of the conical ring.
CXXX.	4 Nov., '97			.... *b* $x=3''$	206	178	From N.E. to E.N.E.	154	150	152*	2			
CXI.	7 Aug., '97	184		.... *a*	525	495	From S.S.W. to S.W.	134	132	133	2	......	....	For results of experiments upon plain diverging tube 6″ × 27″ see fig. B R, p. 418.
CXI.	7 Aug., '97			.... *b*	425	410	S.W.	136	134	135	2			
CXI.	7 Aug., '97 10 Aug., '97	185		.. .. *a*	447	415	From S.S.W. to S.W. by W.	137	135	136	3			
CXI.	7 Aug., '97 10 Aug., '97			.... *b*	417	299	From S.S.W. to S.W.	140	137	139	2			
CXIII.	10 Aug., '97	186		.... *a*	327	...	From S.S.W. to S.W.	146	139	143	2			
CXIII.	19 Aug., '97			... . *b*	339	143	From S.W. to S. by S.W.	145	145	145	2			

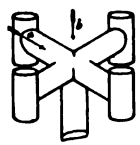
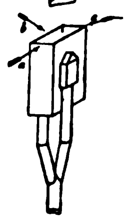
CXXXI.	16 Aug., '97 14 Feb., '98	188		...... *b*	490	186	From W.S.W. to W. by N.	138	125	130	5	S	....	The circumference of this louvre terminal was cut away to the extent of ⅓rd to compare with the 3-in. uncut louvre shown at fig. A Q, p. 412. This was experimented upon with a view to subsequently constructing a twirling louvre, the inside of which will be found at Sketch No. 194.
CXXXI.	16 Sep., '97	189		...... *b*	254	178	From W.N.W. to N.W.	151	150	150	3			
CXXXI.	17 Sep., '97 21 Sep., '97	190		...... *b*	498	191	From W. to N.N.W.	143	137	140	7	......	....	This terminal may be compared with that shown at fig. A D, p. 404. The rainguage cap might be made to twirl in a similar way to the cap at Sketch No. 213.
LVI[L.]	1 Feb., '98 3 Feb., '98	191		...... *a*	649	455	From W.S.W. to W. by N.	118	116	117	4	S	....	For experiments without louvre see Sketch No. 40.
LVI[L.]	1 Feb., '98 3 Feb., '98			...... *b*	591	530	From W.S.W. to W. by N.	108	105	107	4			
LVI[L.]	1 Feb., '98 3 Feb., '98			...... *c*	566	475	From W.S.W. to W. by N.	106	105	106	4			

Sheet.	Date.	Sketch of Terminal.		Velocity of Cups, feet per minute. Max.	Min.	Direction of Wind.	Efficiency. Max.	Min.	Average	Number of Experiments.	Reference Letters.	Angle from vertical at which downdraught is observed.	Remarks.
LVI[L.]	3 Feb., '98	192 	...........a	508	437	From W. by S. to W. by N.	116	112	114	2	...	... .	For experiments without louvre see Sketch No. 41.
LVI[L.]	3 Feb., '98		...........b	601	598	From W.S.W. to W.N.W.	103	102	103	2			
LVI[L.]	3 Feb., '98		c	623	563	From W.S.W. to W. by N.	110	110	110	2			
						TWIRLERS.							
LXVI.	24 Aug., '86	193 	....	243	121	From W.N.W. to N.N.W.	119	109	114	4	......	....	This terminal represents the bevelled pipe shown at fig. Y, p. 403, put into a practical form. See remarks at Sketch No. 195, and for fixed form of terminal see Sketch No. 188.
LXXXII.	14 Feb., '98	194 	4 feathers	319	219	From W. to W.N.W.	121	118	120	3	......	....	This construction was designed on the same lines as the louvres with 4 feathers and 9 feathers, but cutting away a portion of the circumference, together with its feather attachment, reduced the number of feathers to 3 and 7 respectively. Comparable as 4 feathers (1 being cut away).
LXXXII.	12 Feb., '98		9 feathers	503	367	From S.W. by S. to W.N.W.	110	99	105	4	......	....	Comparable as 9 feathers (2 being cut away).
LXXXII.	14 Feb., '98												
LXXXII.	12 Feb., '98	195 	....	488	385	From S.S.W. to S. W.	106	105	106	3	......	....	For similar terminal with fixed top see Sketch No. 36. Some loss in the upcast is due to the twirling form, as shown by the decline of efficiency from 127 to 106. This may be partly accounted for by the necessary con-

LXXVII.	10 May, '95 13 May, '95 17 May, '95 25 May, '95 28 May, '95	198		.. ..	447	113	From E. to N.N.W.	105	85	96	19	I 285 DB R*	....	* This terminal, the results of which have not been plotted in diagrammaic form, gives an efficiency from 89 in a Westerly wind to 108 in a South-westerly or North-westerly direction (see Sketch No. 298, p. 444). A few experiments were also tried on sloping roof with a 9-in. flange 6-in. below lobster and gave an increased efficiency in a Westerly wind; but these have been excluded from the Sloping Roof Tabular Reproduction as the tests were insufficient in number.
LXXVII. LXXVIII.	17 May, '95 25 May, '95 28 May, '95	199		....	405	138	From N.E. to N.N.W.	100	90	95	11	I 283	....	The twirling portion or lobster-back of this terminal is not the same as the one shown in Sketch No. 198, but was specially made to he same dimensions for experimental purposes with narrow crossbars twirling over a slightly diverging fixed portion. The Committee anticipated that by introducing a diverging piece below the lobster an increased efficiency would be obtained, but results show that the gain, if any, is more than counterbalanced by the loss due to the reduction in the annular space.
LXXVIII.	21 May, '95	200		....	206	123	N.N.E.	97	90	94	3			
LXXVIII.	21 May, '95	201		....	138	136	N.N.E.	90	88	89	3			
LXXVIII.	31 Jan., '98	202		.... a	397	302	From W. to W. by N.	95	93	94	3	S	....	These experiments were tried with the object of ascertaining the effect of fixing a number of feathers to the top of the pipe around which the lobster twirled
LXXVIII.	17 Sep., '97			.... a	649	397	From W. by S. to W. by N.	110	106	108	2			
				.... b	453	387	From W. by S. to W.N.W.	101	101	101	2			
LXXVIII.	31 Jan., '98			.... a	360	344	From W.N.W. to N.W.	108	105	107	2			
				.... b	377	324	W.N.W.	106	103	105	2			

Sheet.	Date	Sketch of Terminal.			Velocity of Cups, feet per minute. Max.	Min.	Direction of Wind.	Efficiency. Max.	Min.	Average.	Number of Experiments.	Reference Letters.	Angle from vertical at which downdraught is observed.	Remarks.
							TWIRLERS *(continued).*							
LXXVIII^A.	17 Sep., '97	203		*a*	420	334	From W.S.W. to W.N.W.	108	106	107	2			
LXXVIII^A.	17 Sep., '97			*b*	485	365	From W. by S. to W.N.W.	107	103	105	2			Compare with terminal shown at Sketch No. 202, also fig. B A, p. 414 (9 feathers).
LXXVIII^A.	31 Jan., '98 15 Feb., '98	204		*a*	661	302	From W.S.W. to N.W. by W.	117	114	115	4	D B R*	....	This terminal gave a fairly good result when tried on sloping roof; efficiency about 100 in winds at right angles to ridge, and about 120 in winds at 45° from ridge (see Sketch p. 444).
LXXVIII^A.	31 Jan., '98 15 Feb., '98			*b*	571	309	From W.S.W. to W.N.W.	117	110	114	4			* Also tried on sloping roof with 9-in. flange 6 inches below louvre, and gave an increased efficiency in winds at right angles to ridge (see Sketch p. 444).
LXXVIII^A.	15 Feb., '98	205		*a*	571	473	From W.S.W. to W.	129	126	128	2	......	....	The flange was added in this case to increase the upcast.
LXXVIII^A.	....			*b*	596	566	From W.S.W. to W.	129	129	129	2			
LXXIX.	9 Sep., '84 10 Sep., '84 19 Jan., '95 26 Mar., '96 9 Apl., '96	206		...	561	251	From E. to N.W. by N.	108	99	103	13	I 288		
LXXIX.	25 Aug., '86 19 Jan. '95 9 Apl., '96 10 Apl., '96	207		...	416	178	From S. by E. to N.	117	99	107	11	I 289		
LXXIX.	9 Apl., '96	208		...	246	128	From W. to N.W.	105	101	103	3			

LXXX.	24 May, '95 9 Apl., '96 10 Apl., '96	211		... $x=1''$	485	126	From E. by N. to N.W. by N.	113	99	107	13			
LXXX.	28 May, '95 26 Mar., '96 28 Mar., '96 10 Apl., '96			... $x=2''$	646	277	From E. by N. to N.N.W.	123	102	113	14			
LVI[B].	4 Aug., '96 11 Aug., '96	212		....	432	121	From N.N.E to N. by W.	123	104	114	5	I. 284 DB R*	....	This terminal would probably show a better upcast efficiency if made to set itsel more readily in light winds. For sloping roof results see Part V., p. 421, also fig. CA, p. 421, from which it will be noticed that the best result of this terminal was obtained when the wind blew at right angles to the roof. * Also tried on sloping roof with flange 6-in. down from orifice. Provisional patent number 16735.
LXXXI.	24 Aug., '95 9 Oct., '95 11 Oct., '95	213		... $x=\frac{1}{2}''$	246	116	From W.S.W. to N.W. by W.	131	122	126	8	DB R*	....	213. Two experiments were previously tried with crossbar below notch, and resulted in an efficiency of only 97 per cent. In these experiments therefore the crossbar was raised above notch, thus removing the obstruction. See also fig. A C and A D, p. 404. * Only three experiments were made with terminal placed on sloping roof, and gave an efficiency of about 80 in Westerly winds.
LXXXI.	22 Aug., '95 24 Aug., '95 11 Oct., '95 2 Nov., '95			... $x=1''$	460	128	From E.N.E. to N.W. by N.	137	124	131	12			
LXXXI.	22 Aug., '95			.. $x=1\frac{1}{2}''$	422	357	From S.S.W. to S.W.	134	131	132	3			
LXXXI.	23 June, '96	214		....	440	349	From S.W. to W. by W.	130	129	130	5			
							EXPERIMENTS WITH SIX-INCH TERMINALS.							
X. & XI.	Various.	215		... .	.....	.....	....	......	......	100	48	.....	....	See remarks at Sketch No. 1.
CLX.	8 Aug., '88	216		.... a	410	342	S.W.	124	119	122	3	.....	....	See Sketch No. 35A; also General Notes *re* square types. Neither the round nor the square 6-in. open pipes were tried for downdraught, as the unprotected orifice would manifestly induce downdraught in position A.
CLX.	8 Aug., '88			.... b	435	392	From S.W. to W.	112	103	106	3			

Sheet.	Date.	Sketch of Terminal.	Velocity of Cups, feet per minute. Max.	Min.	Direction of Wind.	Efficiency. Max.	Min.	Average.	Number of Experiments.	Reference Letters.	Angle from vertical at which downdraught is observed.	Remarks.
											A = Down-blow. B = Up-blow.	
CLX.	9 Mar., '87 28 Mar., '87	217 	446	233	From W. to N.N.W.	116	109	112	3			
CLX.	22 Aug., '88	218 	465	440	W.N.W.	152	145	148	3	......	....	See also Sketch No. 29.
CLX.	22 Aug., '88	219 	458	292	W.N.W.	132	131	131	3	......	....	See also Sketch No. 30.
CLXII.	31 Mar., '87	220  ...... a	446	388	W.	112	111	112	2	......	....	This Terminal was also tried with its various orifices closed and open alternately, but the results are too complicated for entry here. See also Sketch No. 55.
CLXII.	31 Mar., '87	...... b	562	476	W.	120	119	120	2			
CLXII.	22 Aug., '88	221  ...... a	447	447	W.	......	......	136	1	......	....	See also Sketch No. 60. No downdraught observed.
CLXII.	22 Aug., '88	...... b	395	395	W.N.W.	......	......	128	1			
CLXII.	22 Aug., '88	 c	649	447	From W.S.W. to W.N.W.	143	138	141	3			
CLXIII.	14 Aug., '88	222  ...... a x=3"	244	131	From N.W. to N.N.W.	116	114	115	3	......	B 30°	See General Notes *re* Square Types. This Terminal presents a pecu-

CLXV.	4 Aug., '88 6 Aug., '88	223		....	61	21	From W.S.W. to W.	108	105	106	3

SMOKE EXPERIMENTS.

THE numbers given in the account of the experiments on terminals show that it is possible to increase the upcast flow in the three-inch tube by the addition of a terminal of special shape.

This interesting result is illustrated and largely explained by the series of experiments upon the distribution of smoke issuing from the top of the tube, or from the cowls or terminals surmounting it, which were made by Mr. Farmer in 1897 and 1898.

The curling downward in eddies of smoke issuing from the top of a tall chimney is a well-recognised phenomenon, and the production of these eddies has a marked effect upon the flow of air. In order to obtain definite information as to the distribution of these eddies, the central pipe at the Hut was supplied with smoke by burning paper soaked in a paste of nitre and sulphur. Careful drawings of the distribution of the smoke at the outlet were made. These drawings are here reproduced, and they should be consulted in comparison with the results which are tabulated and plotted for the terminals. The numbers refer to the sketches in Tables XXVII., XXIX., XXX., XXXIII., and the letters to the diagrams commencing on p. 397. The corresponding upcast results may be seen in Table XXVII., where "S" indicates that the terminal has been tested with smoke.

The illustrations have been prepared from rough sketches made at the time of the experiments, as it was thought better to reproduce the original sketches than to have more finished drawings made.

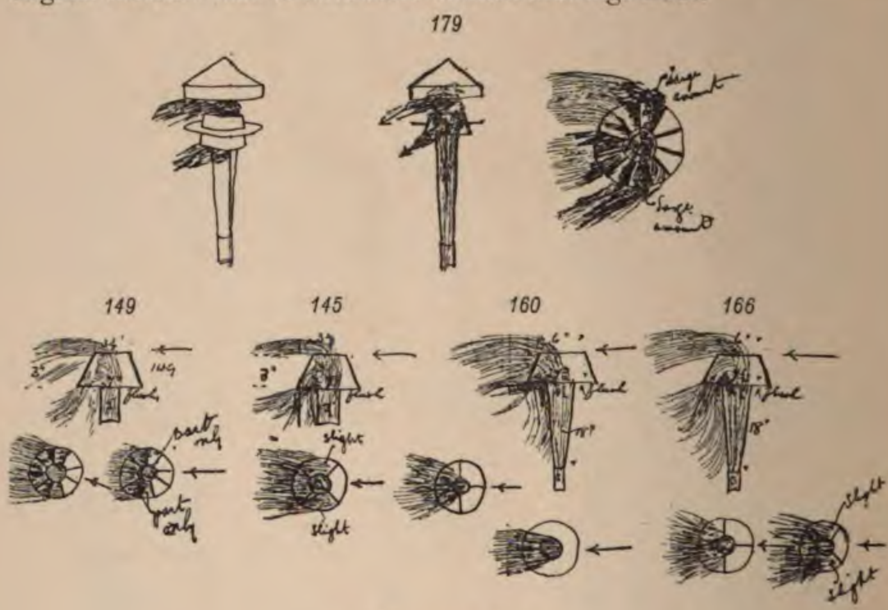


Diagram 51.

Smoke Observations, November, 1897.

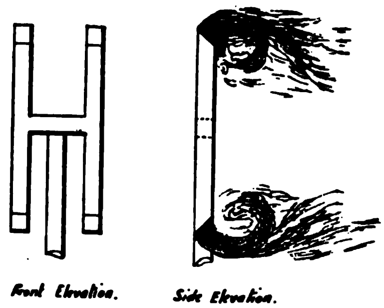
The original Sketch Numbers on this Diagram should be translated for reference, as follows :—

6541 = I	6545 = 130B	6550 = B J	6555 = B R
6542 = 179	6546 = 130C	6551 = 202	6556 = N
6543 = 130A / 131	6547 = 131	6552 = 188	6557 = N
6544 = B H	6548 = 101	6553 = B R	6558 = N
	6549 = 102	6554 = 149	

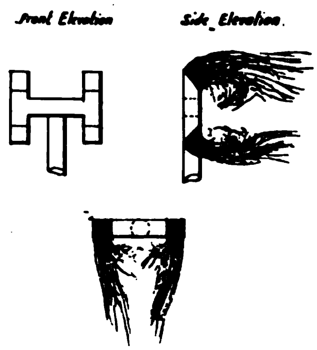
NOTE.—130A to 130C similar to 130 but with feathers as shown.

Diagram 52.

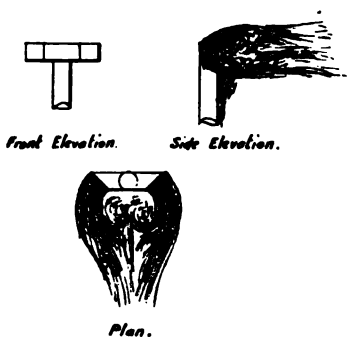
Smoke Observations.



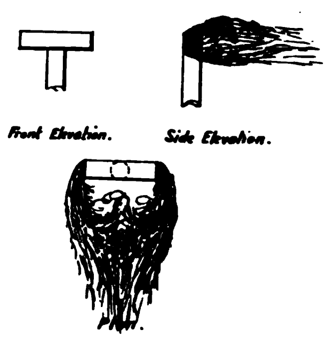
65



63



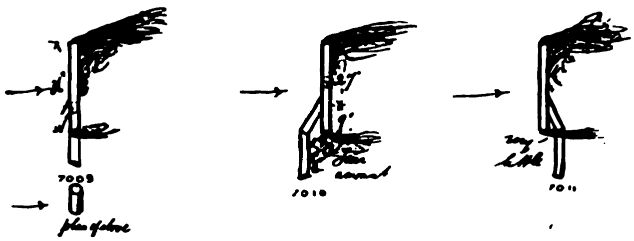
62



61

Diagram 53.

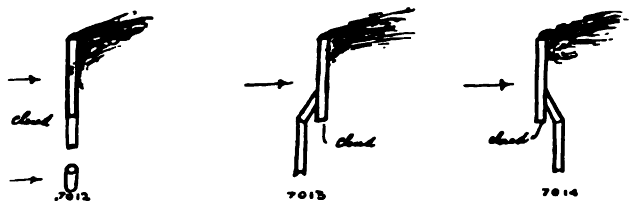
Smoke Observations.

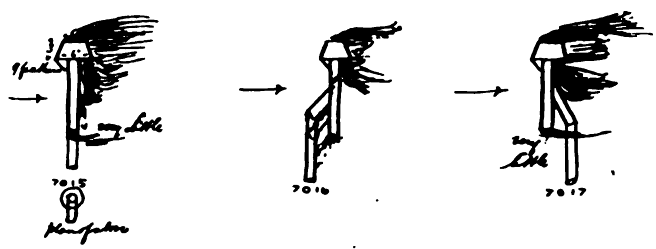


Similar to 43 but open at bottom.

The above are open top and bottom, the greatest amount of smoke coming out at the top.

43



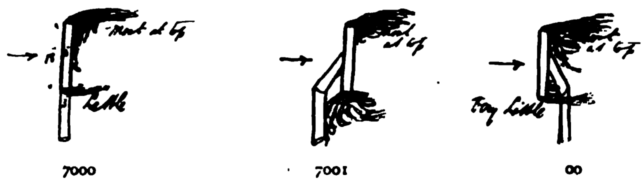


191

The above are open both ends.

Diagram 54.

Smoke Observations, 9th February, 1898.

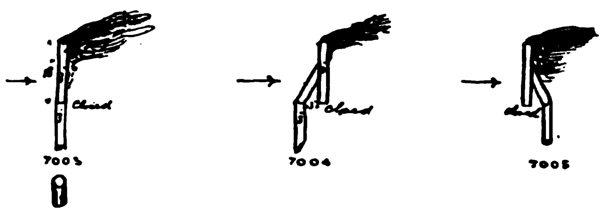


40

Plan of above.

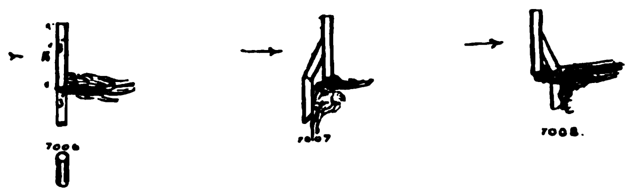
The above are open top and bottom. By far the greatest quantity comes out at the top.

41



The above are open at the top and closed at the bottom.

42



The above are open at the bottom and closed at the top.

Diagram 55.

Smoke Observations.—(*Continued*).

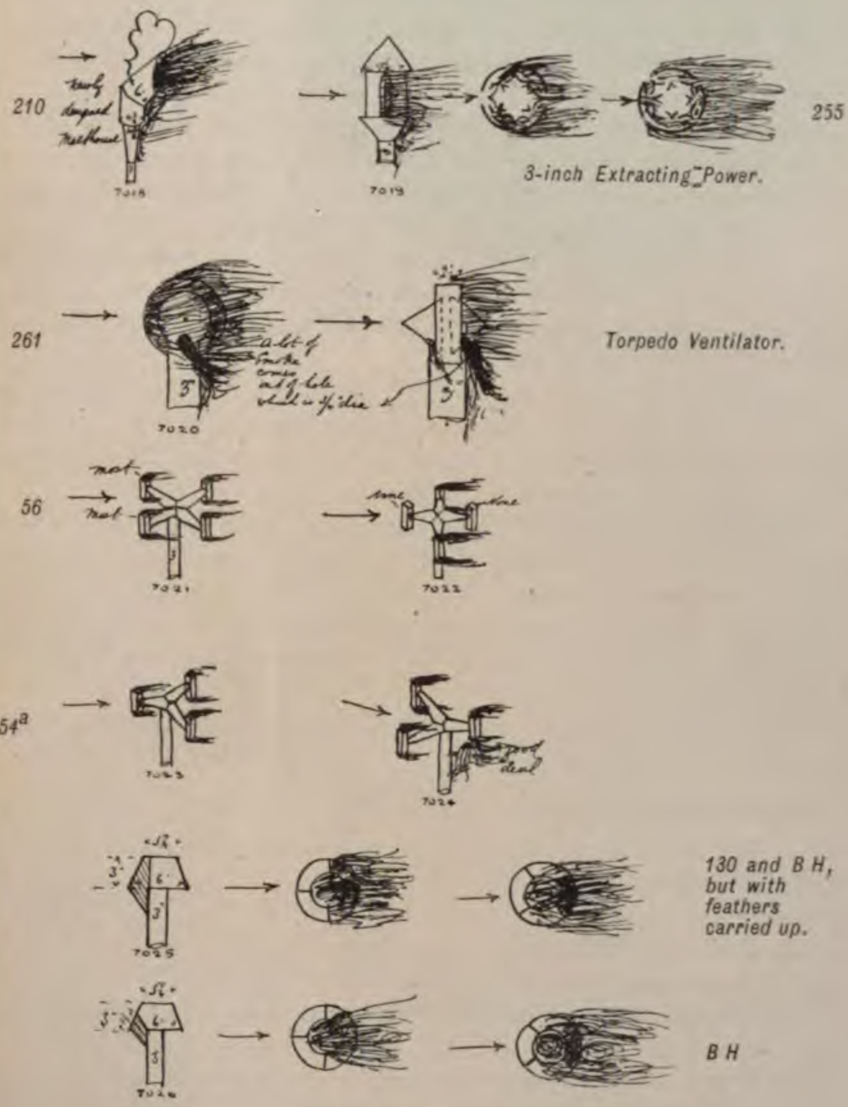


Diagram 56.

The observations of the action of the smoke, in particular the free formation of the eddies on the leeward side of the pipe carrying the best terminals which are here reproduced, led to a special inquiry being made into the effects produced by varying one special characteristic or dimension of various terminals, keeping all the others the same. Some experiments of this kind had already been made, and among those which followed the experiments with smoke may be specially mentioned the tests of the effects upon louvre and sugar loaf terminals of varying such elements as the dimensions of the louvre, its best number of feathers, its height above or below the orifice of the pipe, the position of a flange or fillet.

It should be premised that Louvre Terminals are truncated cones, in which the length of the side is less than the diameter of the base (in a few exceptional instances, such as experiment 5679, etc., the height has been increased for experimental purposes).

Sugar Loaf Terminals are truncated cones, in which the length of the side is greater than the diameter of the base (in a few exceptional instances, such as the $4\frac{1}{2}$ in. × $7\frac{1}{2}$ in. × 6 in. sugar loaf, the height has been decreased for experimental purposes).

It may also be mentioned that a Raingauge Cap is understood to be an inverted cone with a vertical angle of 60°, and surmounting a cylindrical band of various dimensions. The most satisfactory results for a rain-gauge cap for a 3-in. pipe is shown on diagram 76 at fig. BJ, p. 416, and a $4\frac{1}{2}$-in. diverging tube in fig. BK. (See also Complete Tabulation Sheet, p. 396.)

The details of these experiments will be sufficiently understood from the curves represented on diagrams 57 to 82, figs. A to CC.

The following notes should be added:—

(*a*) Fig. N.—This terminal was tried on sloping roof with the flange flush with orifice of pipe; also with flange 3 ins., 6 ins., and 9 ins. below the orifice.

(*b*) Fig. BD.—The general average for nine feathers from twenty-eight experiments (Complete Tabulation, Sheet CXXVIII.*) is 153.

(*c*) Fig. BK.—This diverging tube, surmounted by 13-in. rain-gauge cap, was tried for down-draught, with board at back of terminal.

(*d*) Fig. BR.—Diverging tube experiments, with and without flange, were tried on sloping roof. The $4\frac{1}{2}$-in. × 18-in. diverging tube was tried for down-draught, with board at back of terminal.

* Not reproduced.

Table XXVIII.—DOWN-DRAUGHT EXPERIMENTS.

(See p. 437).

Reference Letters to Figures on Diagrams 57 to 82.	Angle from Vertical at which downdraught is observed.	REMARKS.
		A = Inclined towards wind.* **B** = Inclined away from wind.
H. $x = 4$ ins.	....	No downdraught observed.
$x = 6$ ins.	**B** 60°	
$x = 8$ ins.	**B** 40°	
O. $x = 4$ ins.	....	No downdraught observed.
$x = 6$ ins.	**B** 40°	
U.	**B** 40°	
Z.	**B** 30°	
AL.	**A** 50°	Top of Sugar Loaf, 6 ins.
Ditto.	**A** 30°	" " " 7½ ins. (forming a cylinder).
AP.	**B** 40°	
AQ.	**A** 30°	
AR. $x = 1\frac{1}{2}$ ins.	**A** 40° / **B** 60°	
$x = 2\frac{1}{4}$ ins.	**A** 60° / **B** 60°	
$x = 3$ ins.	**A** 60° / **B** 60°	Prior to this test, this louvre measured—top 3 ins., height 3⅝ ins., bottom 7 ins., and gave downdraught both in positions **A** and **B** at 60°.
BG.	**A** 60°	
	B 60°	
BH.	**A** 40°	
BO.	**A** 50°	
BP.	**B** 30°	
BV.	**A** 40°	Pipe inserted 14 ins. into Sugar Loaf.
	B 50°	" " 13 ins. " "
	A 50°	" " 12 ins. " "
	B 50°	" " 11 ins. " "
	B 40°	" " 1 to 10 ins. "
	B 40°	Pipe flush with Sugar Loaf.
	B 30°	Pipe 1½ ins. below bottom of Sugar Loaf.

Reference Letters to Figure on Diagram.	Reference Letter.	
N.	S.	These references are given to show which terminals represented in Diagrams 57–82 were tested with smoke.
BW.	S.	
BJ.	S.	
AX.	S.	

Upon examination of the work upon terminals, summarised in the Complete Tabulation Sheets, it is found that the 3-inch pipe results for a 9-in. rain-gauge cap 1¾ in. above a 5¼-in. × 6-in. louvre 3 inches deep, flanged for protection against downdraught, showed an efficiency of 133, as compared with an open pipe result of 100. This is the best experimental

* See page 297.

upcast efficiency upon a 3-in. pipe obtained by the Committee,* and
sents the average of thirty-one experiments tried on eight different
including three alterations in the assigned positions of the air meter
As the result is likely to prove of peculiar interest, occasion ha
taken in this instance to reproduce, as a specimen of the Co
Tabulation, Sheet CXX. (facing p. 396) in its entirety. In some
columns details have been omitted, because the experimental results
sponding thereto have already been completely entered upon some
sheet.

A still higher value for the ratio was obtained from a termina
sisting of a very long diverging tube having a 5-in. orifice surmoun
a louvre and a rain-gauge cap. (See Table XXVII., sketch No. 17

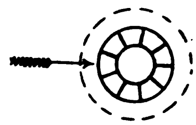
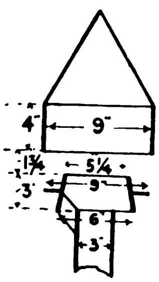
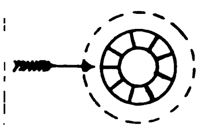
Some special experiments were made to ascertain the effect up
upcast efficiency produced by altering the size and shape of the
supporting $7\frac{1}{2}$-in. and 9-in. rain-gauge caps over a 3-in. pipe; a
varying the fixing of the stays from the outside to the inside of the
The results arrived at were as follows:—

$7\frac{1}{2}$-in. Rain-gauge Cap.

Number of Tabulation Sheet.	Description of shape of Stay.	Size.	How attached to Cap.	Efficiency.	No of Experiments.	Sk
LX^A	U shape.	$\frac{3}{16}$ in.	Outside.	112	3	
LX^A	U shape.	$\frac{3}{16}$ in.	Inside.	113	2	
			9-in. Rain-gauge Cap.			
LX^A	U shape.	$\frac{3}{8}$ in.	Outside.	112	9	
"	"	$\frac{3}{16}$ in.	"	113	10	
"	"	"	Inside.	114	7	
LX^B	V shape.	$\frac{3}{8}$ in.	Outside and wind blowing between two of the four stays.	108	3	
"	U shape.	"	"	114	3	
"	"	"	Inside and wind blowing between two of the four stays.	117	6	

* Provisional Patent Number 16735.

3-in. Terminals
(continued).

25	26	27	28				
Ratio of Col. 19 to Col. 24 Effi-ciency.	Averages.	Rough Sketch of Terminal to scale.	Number on Sheet of Diagrams of Terminals (see Aux. 3).		Index Number repeated.	Remarks. Notes from Original Books are in black. Notes added after Tabulation in 1893 are in red.	For downdraught experiments see sheet
*1·38					6450		
*1·38					6451		
*1·36					6520A		
*1·34					6521		
1·33					6565		
1·36					6566		
1·33					6578		
1·34					6579		
1·23					6624		
1·32	1·32				6625		
1·31					6652		
1·31					6653		
1·25					6677		
1·25					6678		
1·34					6937		
1·34					6938		
1·33	1·33				6939		
*1·39					6452		
*1·38					6453		
*1·34					6522		
*1·33					6523		
1·32					6567		
1·31					6568		
1·37					6580		
1·34	1·33				6581		
1·29					6626		
1·28					6627		
1·32					6654		
1·36					6655		
*1·26					6679		
*1·27					6680		

CURVES OF RESULTS FOR TERMINALS.

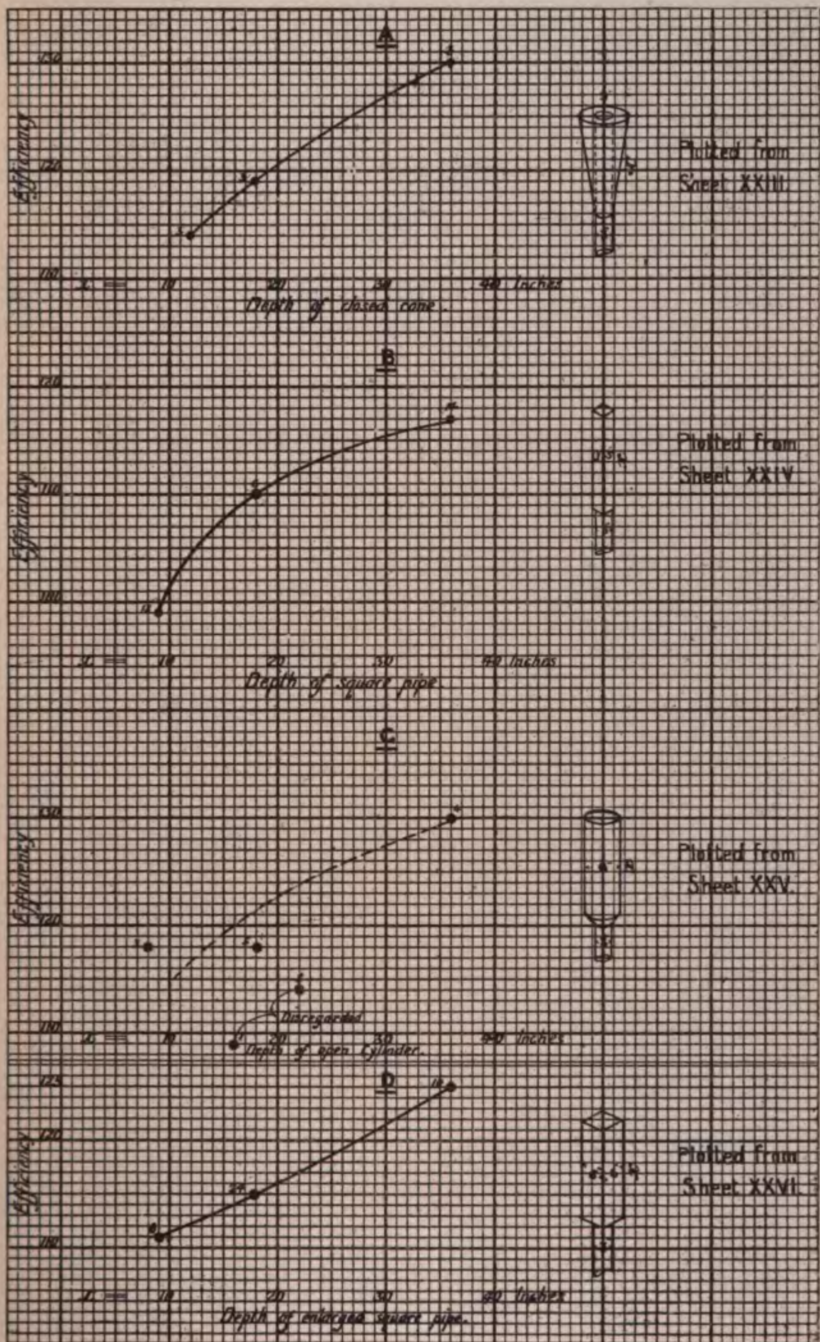


Diagram 57.

CURVES OF RESULTS FOR TERMINALS.

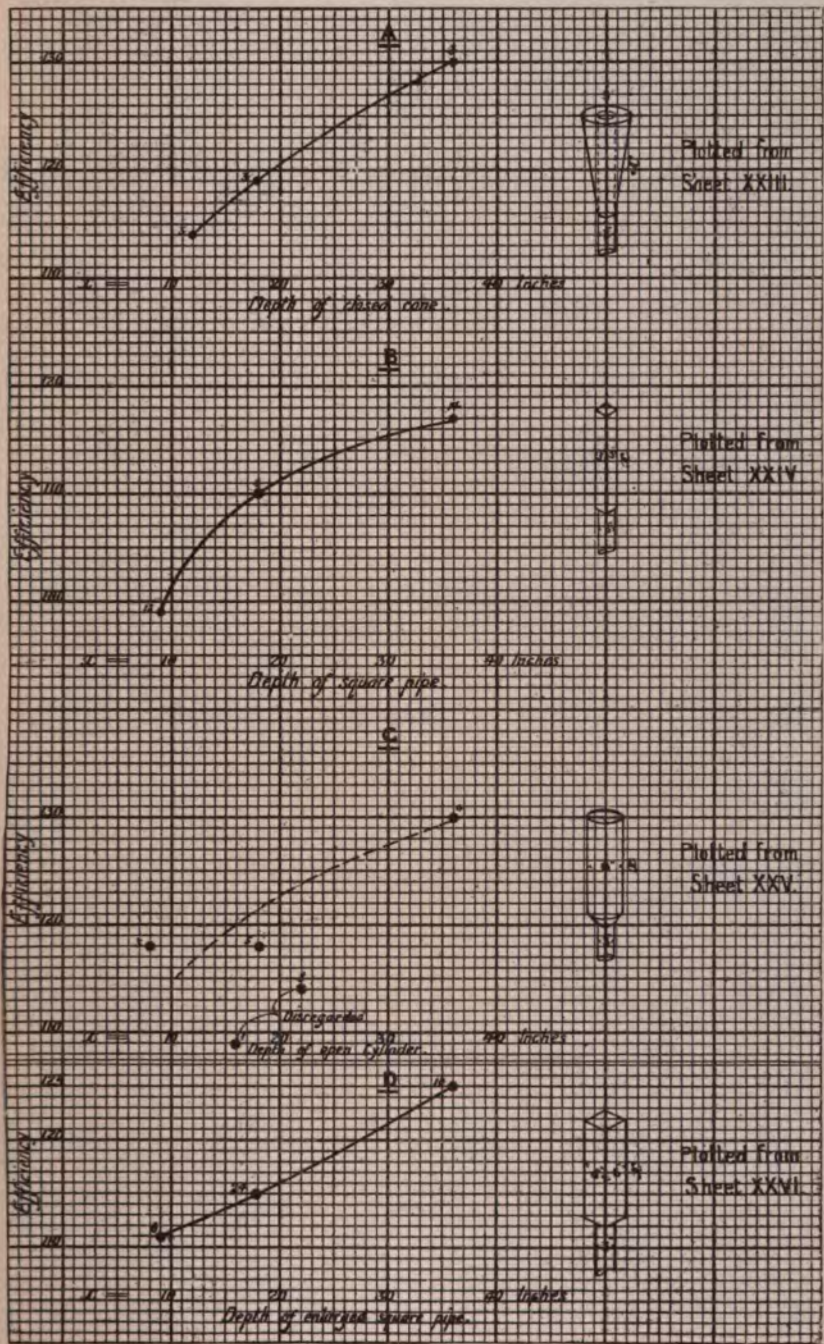


Diagram 57.

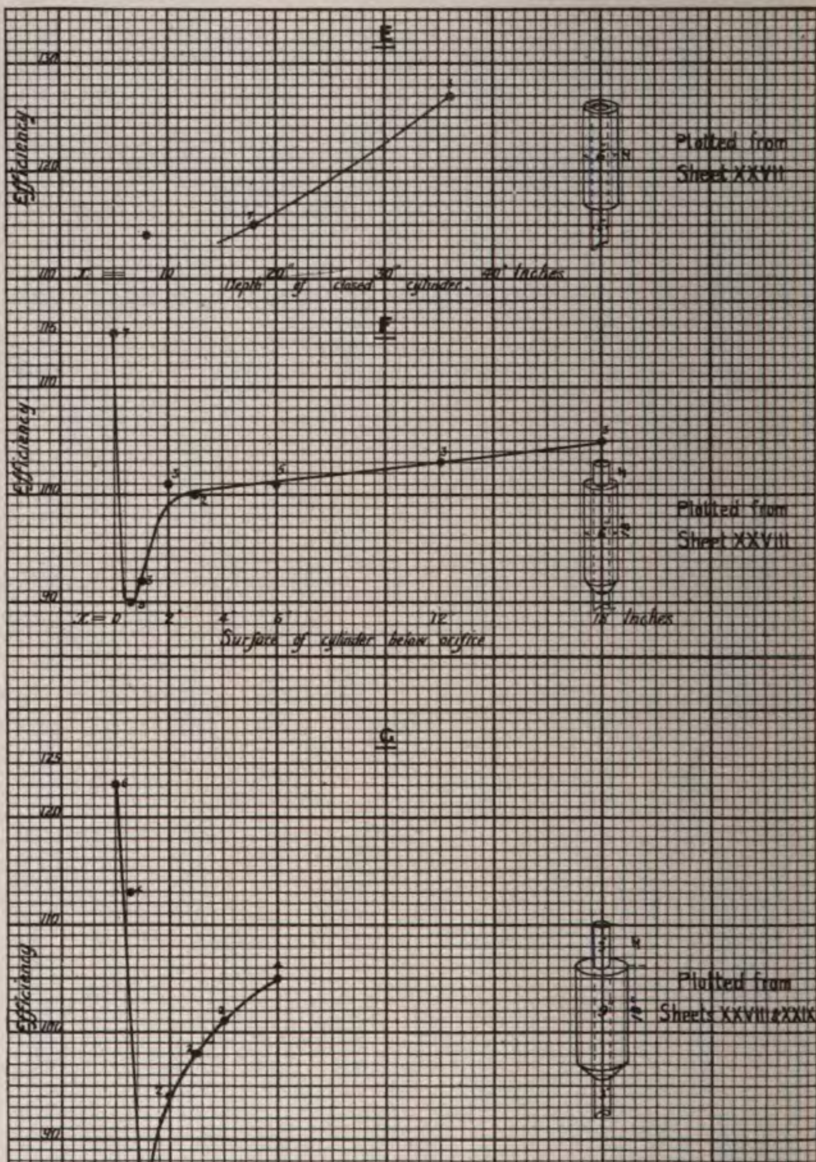

E
Efficiency
Plotted from Sheet XXVII
x = 10 Depth 20" of closed 30" cylinder. 40" Inches
F
Efficiency
Plotted from Sheet XXVIII
x = 0 2 4 6 12 18" Inches
Surface of cylinder below orifice
G
Efficiency
Plotted from Sheets XXVIII & XXIX
x = 0 2 4 6 10 Inches
Surface of cylinder below orifice

Diagram 58.

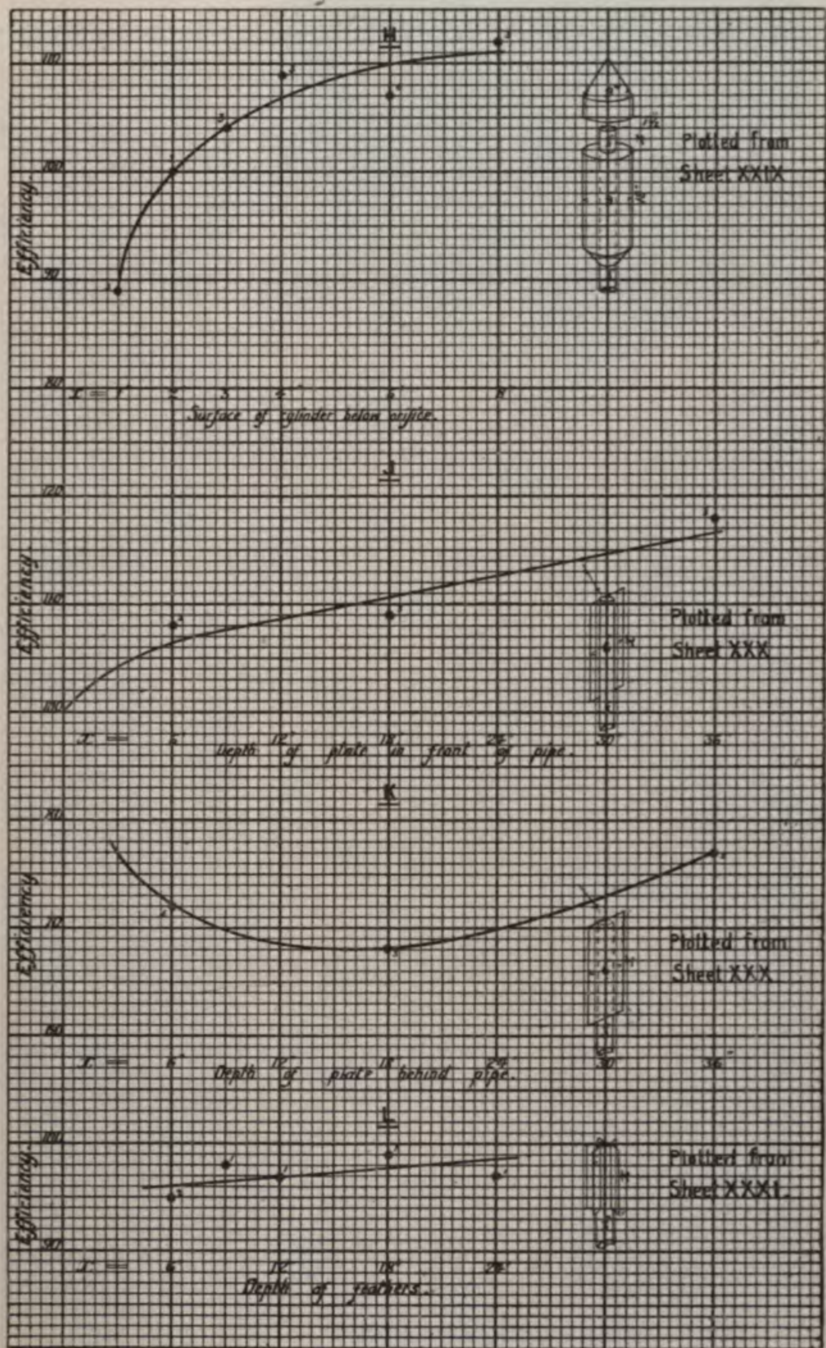

H
Efficiency.
Plotted from
Sheet XXIX
x = 1 2 3 4 6 8
Surface of cylinder below orifice.
J
Efficiency.
Plotted from
Sheet XXX
x = 6 Depth 12" of plate 18" in front 24" of pipe. 30" 36"
K
Efficiency.
Plotted from
Sheet XXX.
x = 6 Depth 12" of plate 18" behind 24" pipe. 30" 36"
L
Efficiency.
Plotted from
Sheet XXXI.
x = 6 12" 18" 24"
Depth of feathers.

Diagram 59.

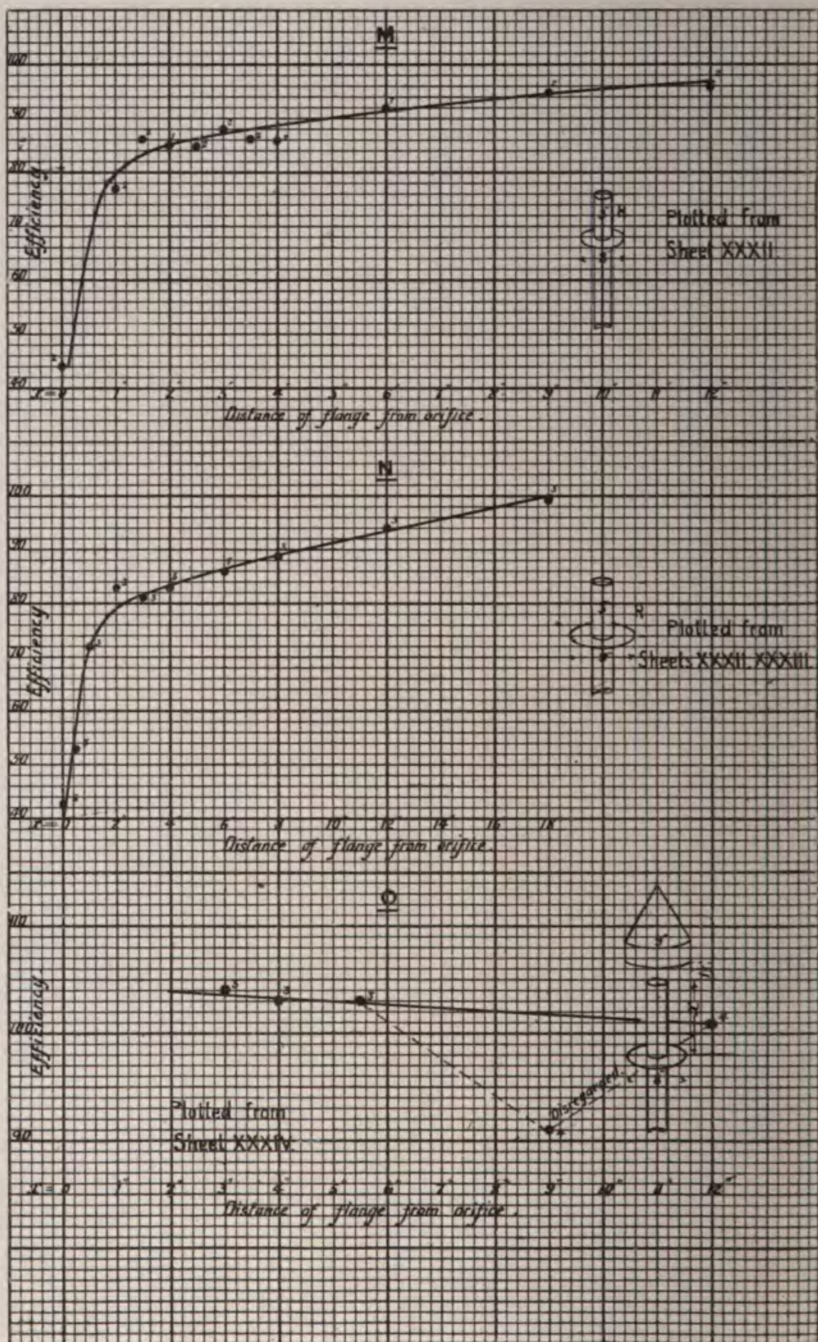

M
Efficiency
Distance of flange from orifice.
Plotted from
Sheet XXXII.
N
Efficiency
Distance of flange from orifice.
Plotted from
Sheets XXXII. XXXIII.
O
Efficiency
Disregarded
Plotted from
Sheet XXXIV.
Distance of flange from orifice.

Diagram 60.

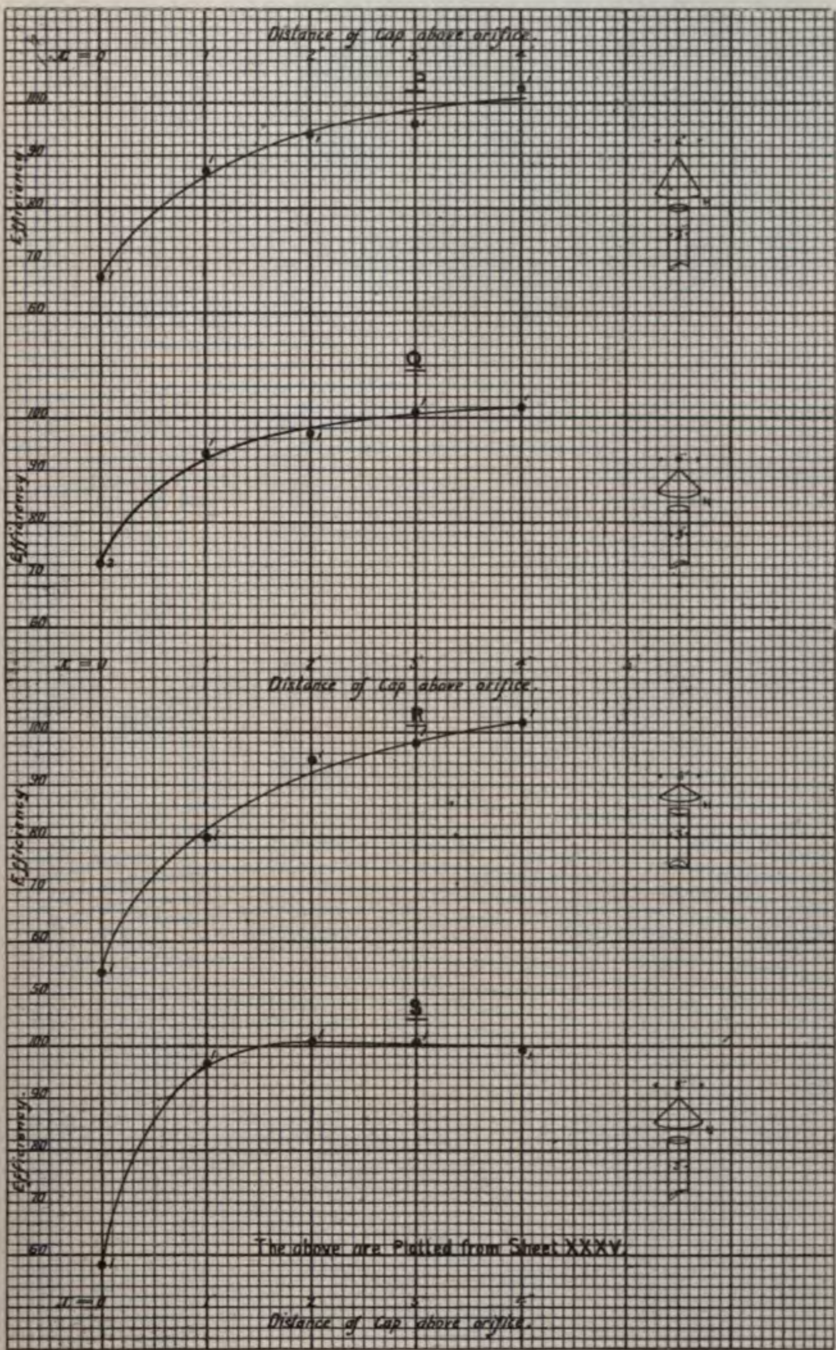

Distance of Cap above orifice.
Efficiency.
P
Q
R
S
The above are Plotted from Sheet XXXV.

Diagram 61.

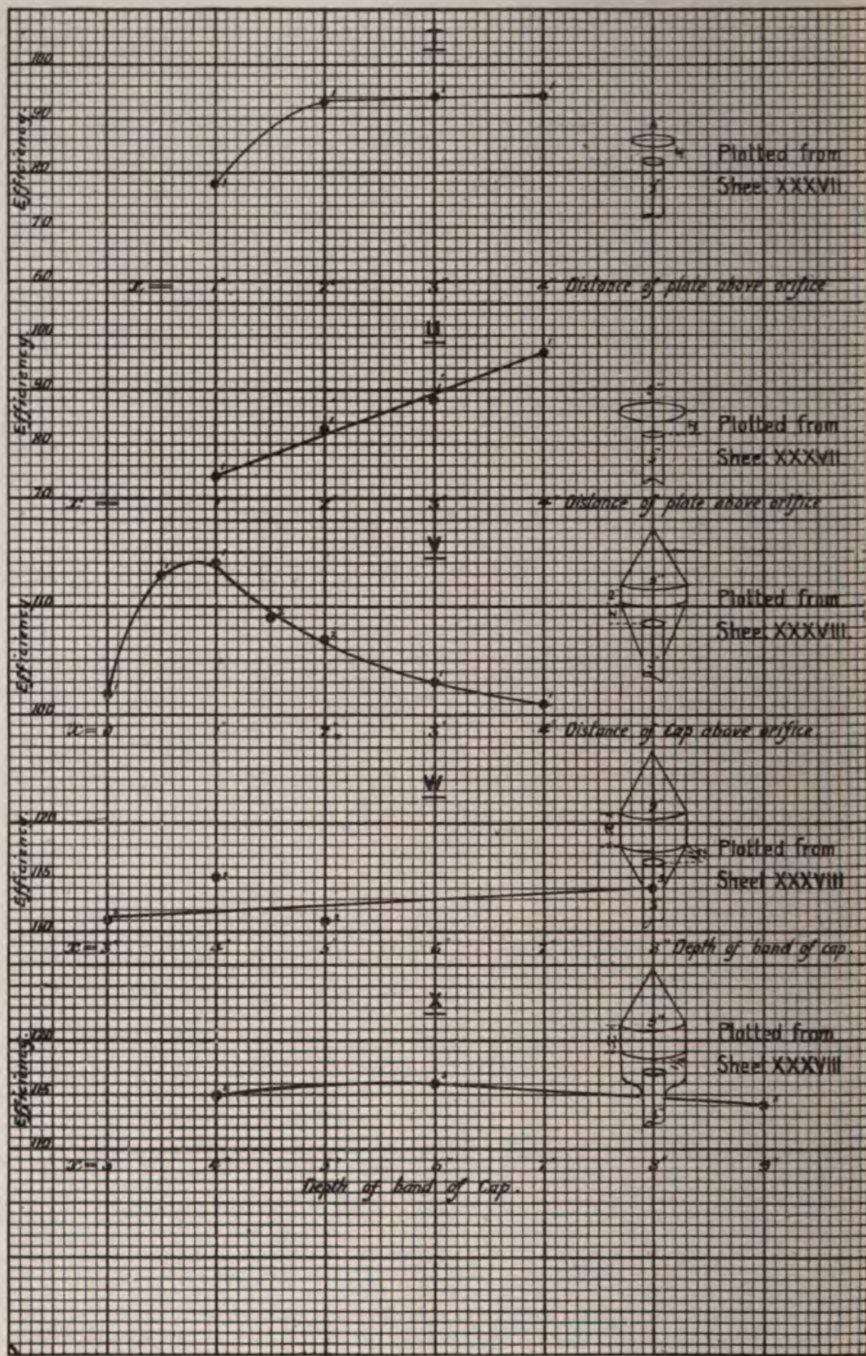

T
Efficiency
Plotted from Sheet XXXVII
x = 1 2 3 4 Distance of plate above orifice
U
Plotted from Sheet XXXVII
Distance of plate above orifice
V
Plotted from Sheet XXXVIII.
Distance of cap above orifice.
W
Plotted from Sheet XXXVIII
Depth of band of cap.
X
Plotted from Sheet XXXVIII
Depth of band of cap.

Diagram 62.

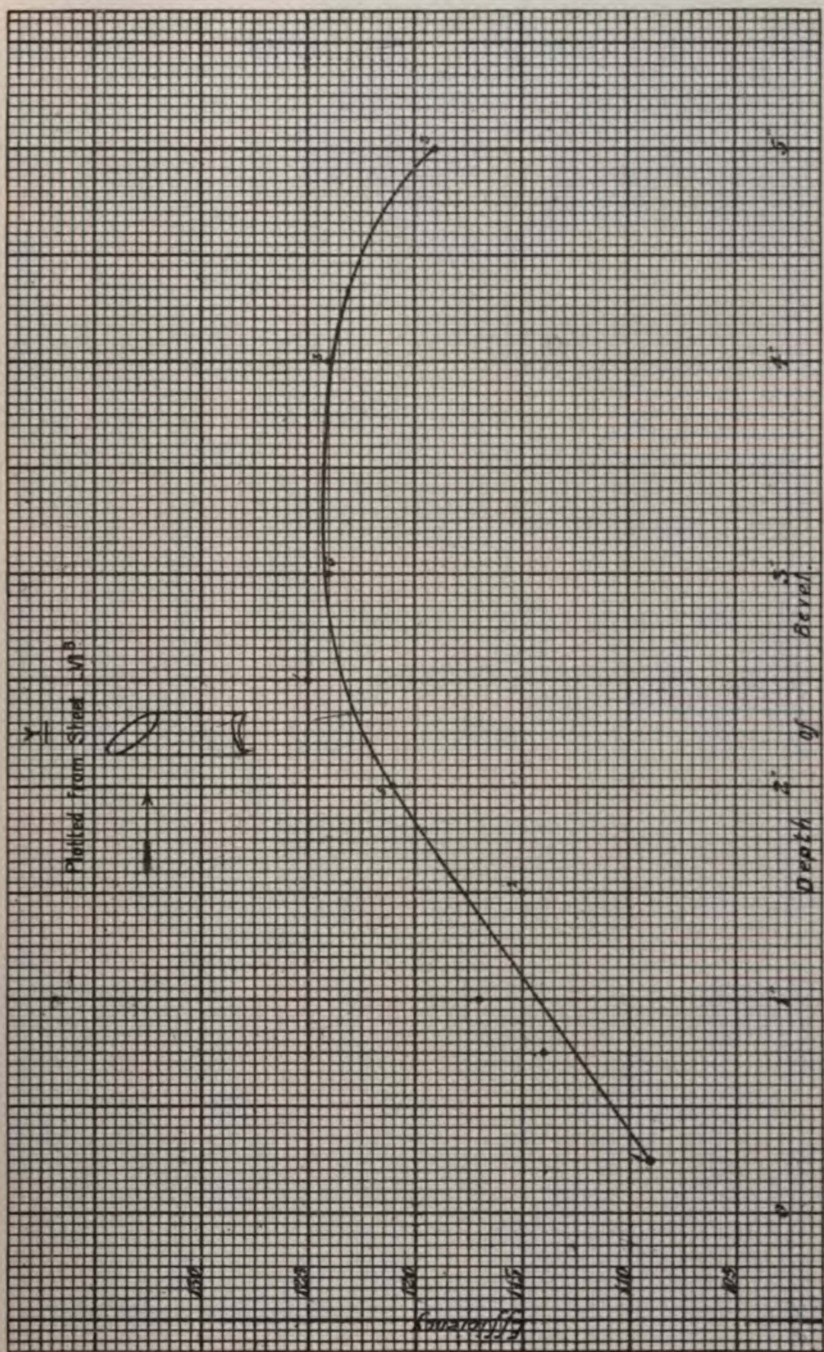

Plotted From Sheet VI
Depth 2" of Bevel.
Efficiency
130
125
120
115
110
105
0
1
2
3
4
5

Diagram 63.

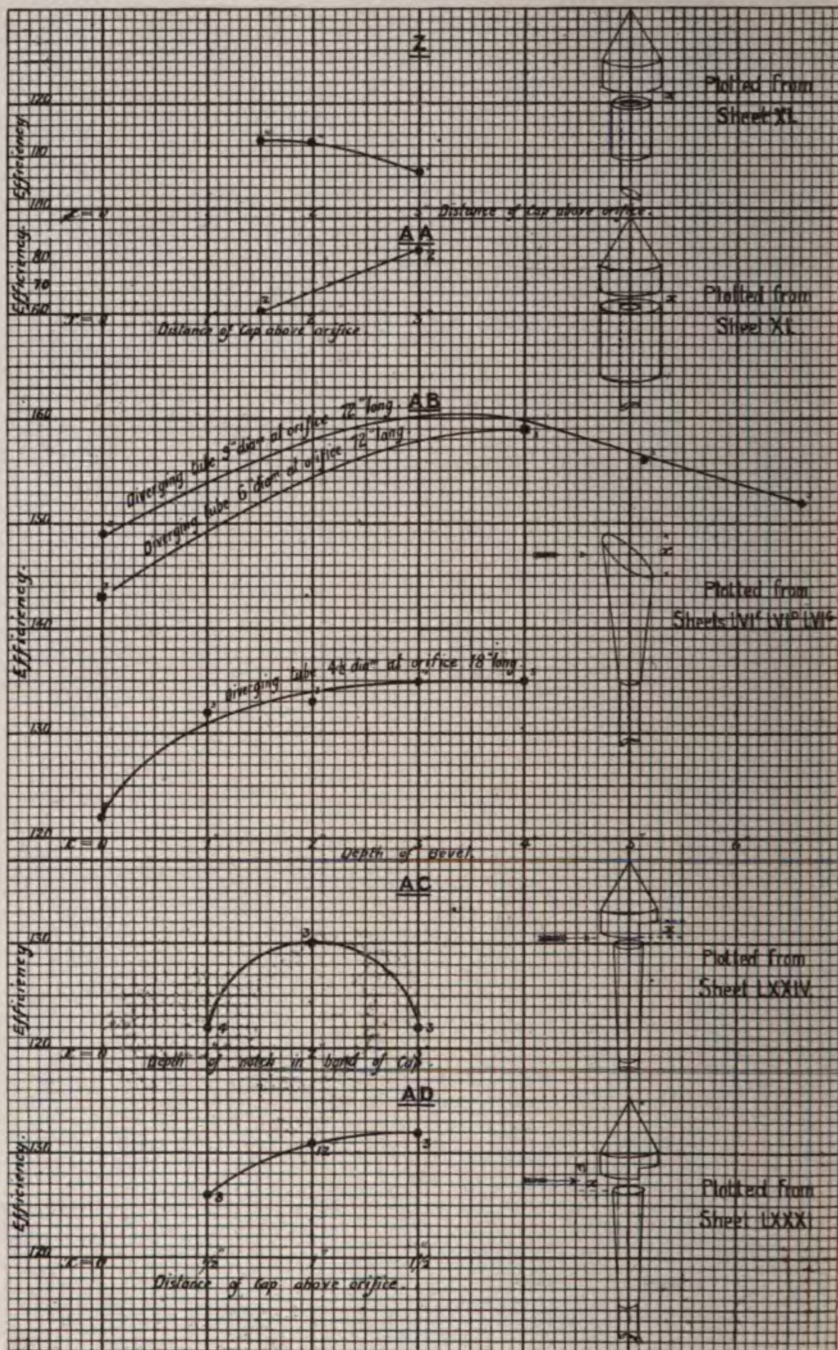

Z
Plotted from
Sheet XL
Efficiency
Distance of cap above orifice
AA
Plotted from
Sheet XL
Distance of cap above orifice
AB
Diverging tube 5" diam at orifice 12" long
Diverging tube 6" diam at orifice 12" long
Plotted from
Diverging tube 4½ diam at orifice 18" long
Depth of Bevel
AC
Plotted from
Sheet LXXIV
Depth of notch in band of cap
AD
Plotted from
Sheet LXXXI
Distance of cap above orifice

Diagram 64.

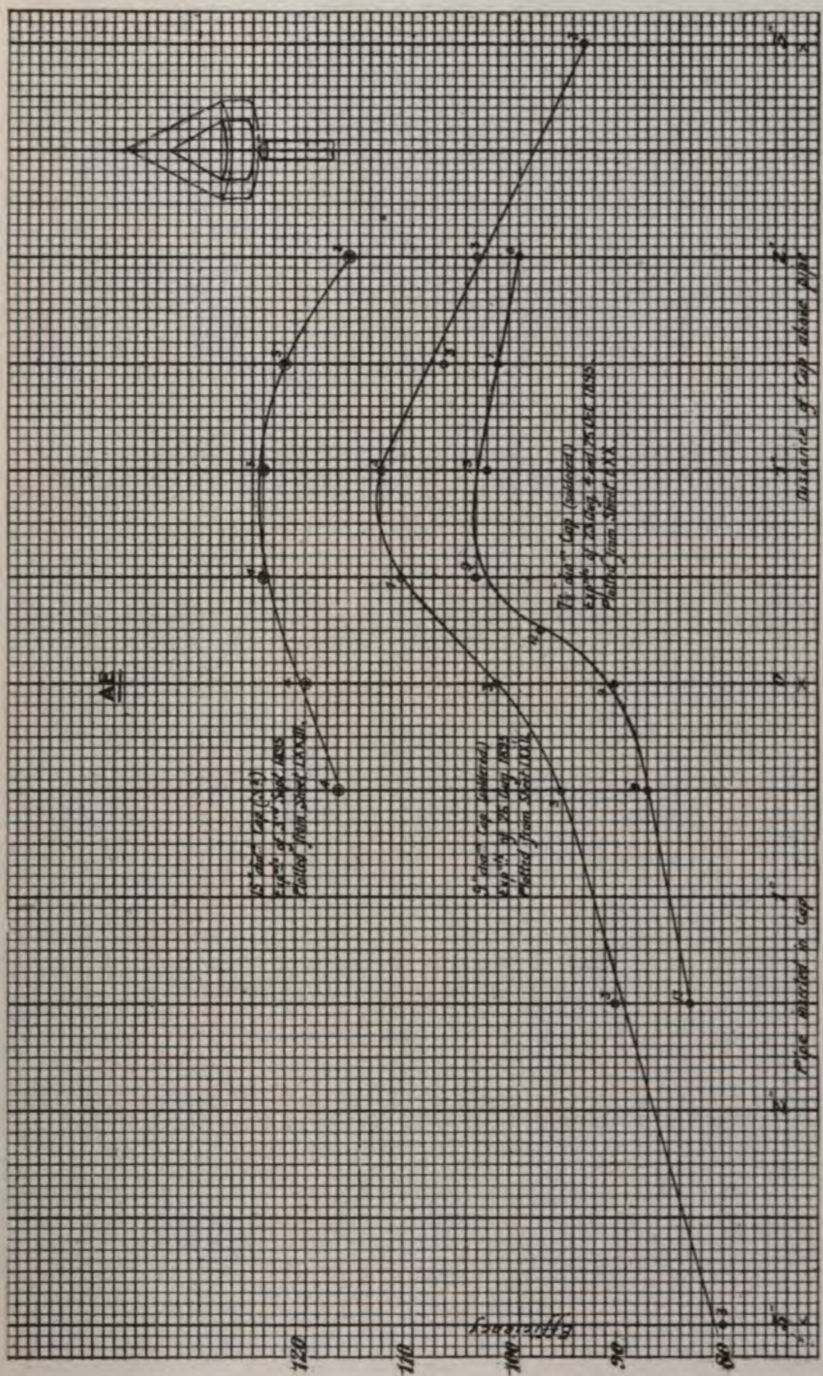

AE
Efficiency
120
110
100
90
80
Distance of Cap above pipe
Pipe inserted in Cap

Diagram 65.

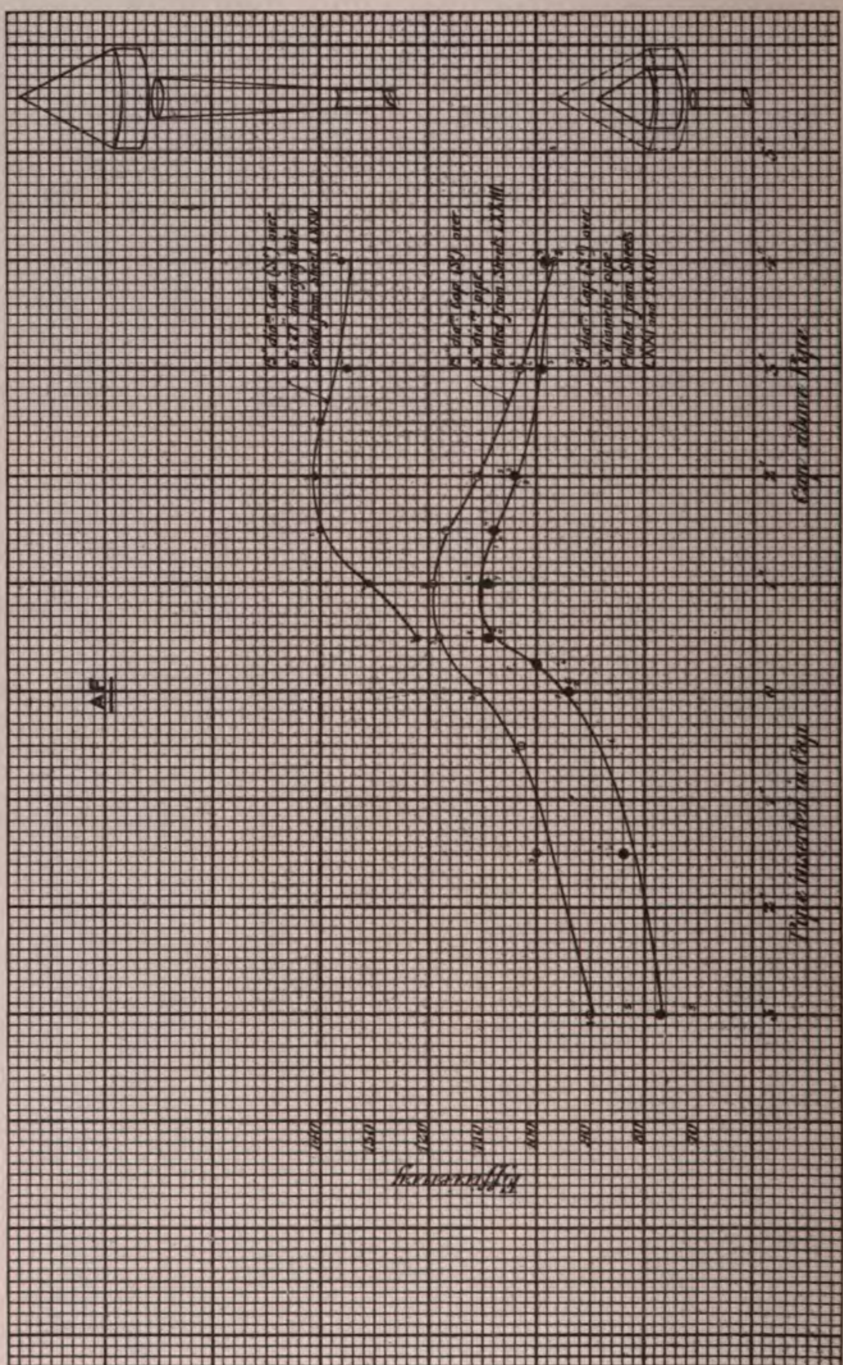


Diagram 66.

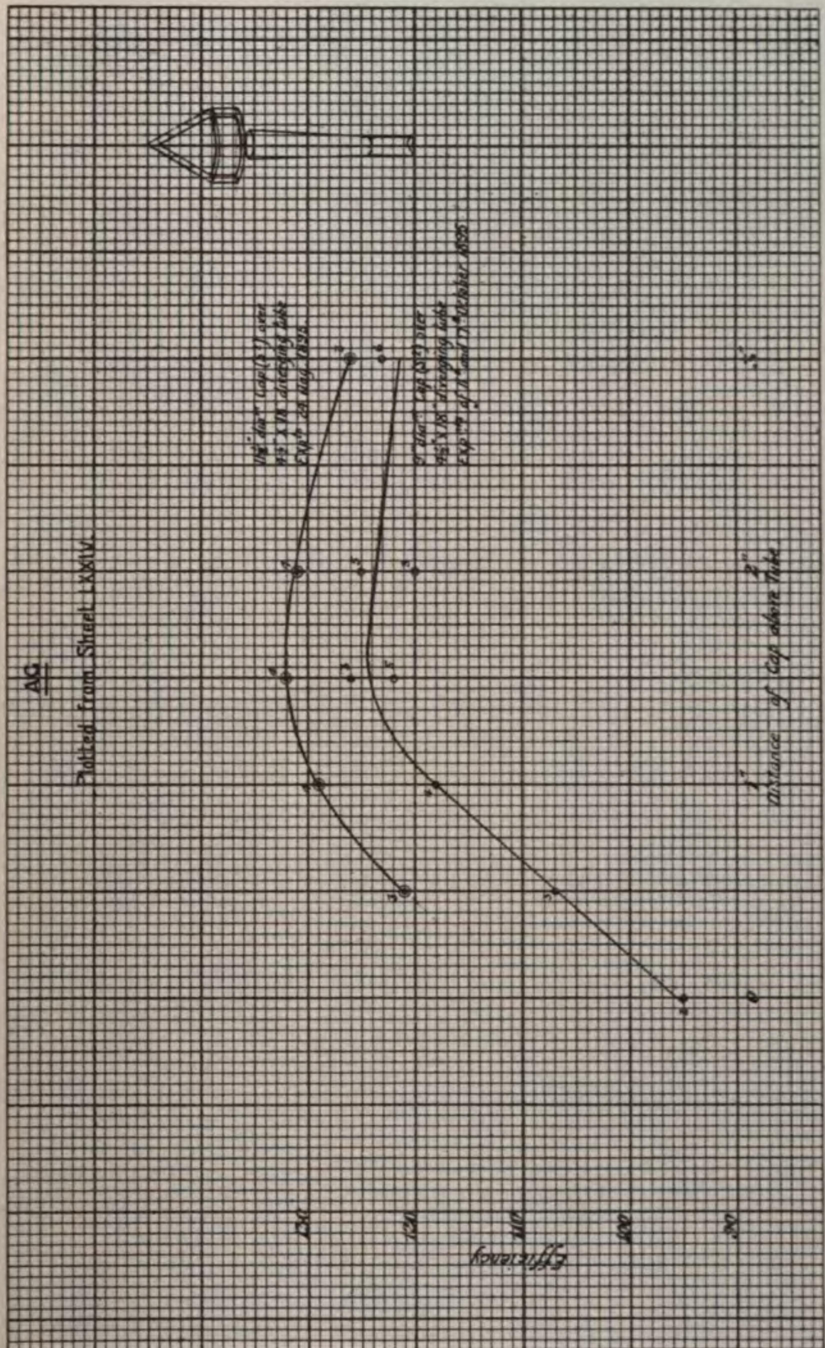

AC
Plotted from Sheet LXXIV
Efficiency
Distance of Cap above Tube

Diagram 67.

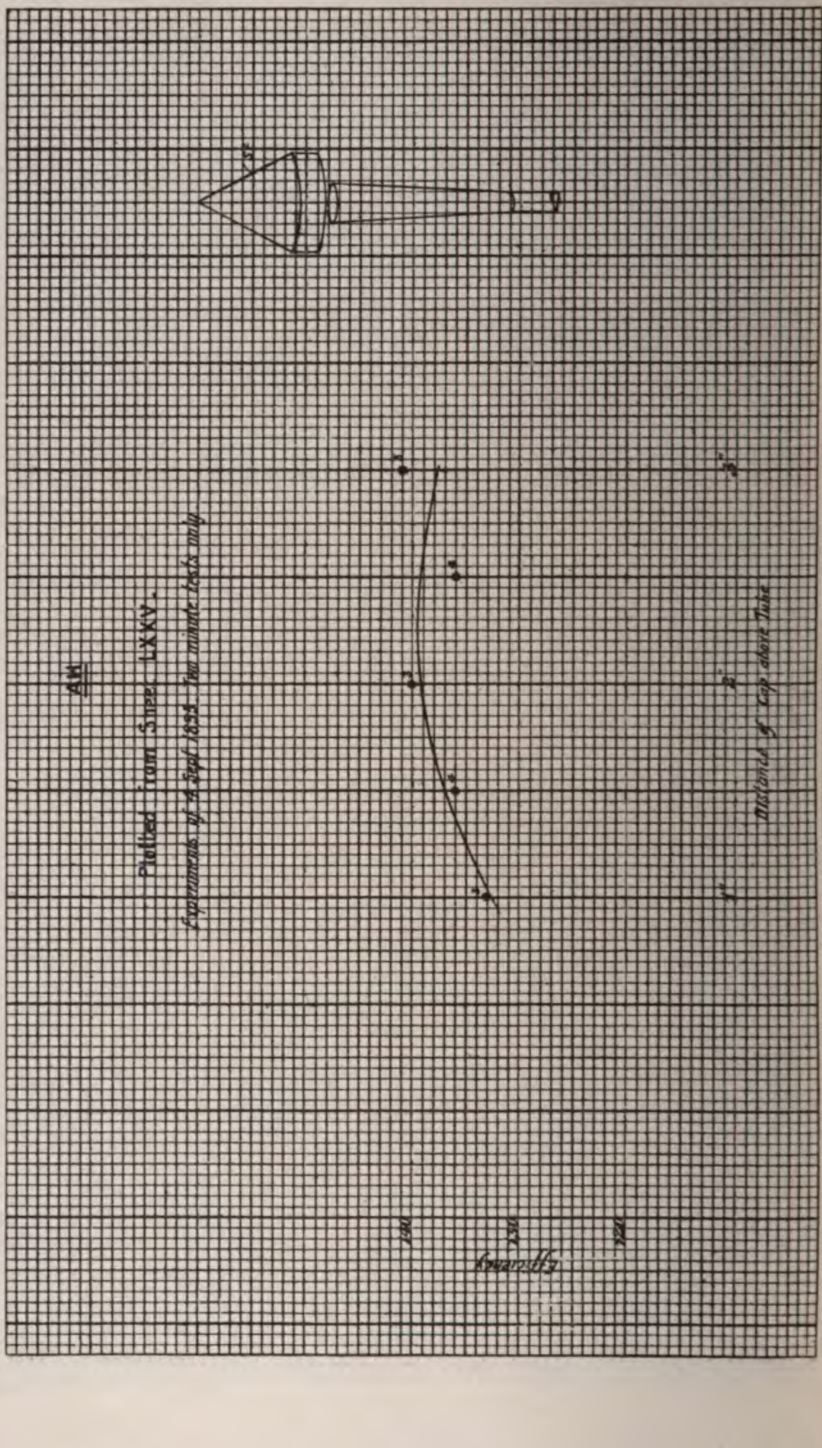

AH
Plotted from Spec. LXXV.
Experiments of 4 Sept 1895 Two minute tests only
Distance of Cap above Tube
1"
2"
3"
Efficiency

Diagram 68

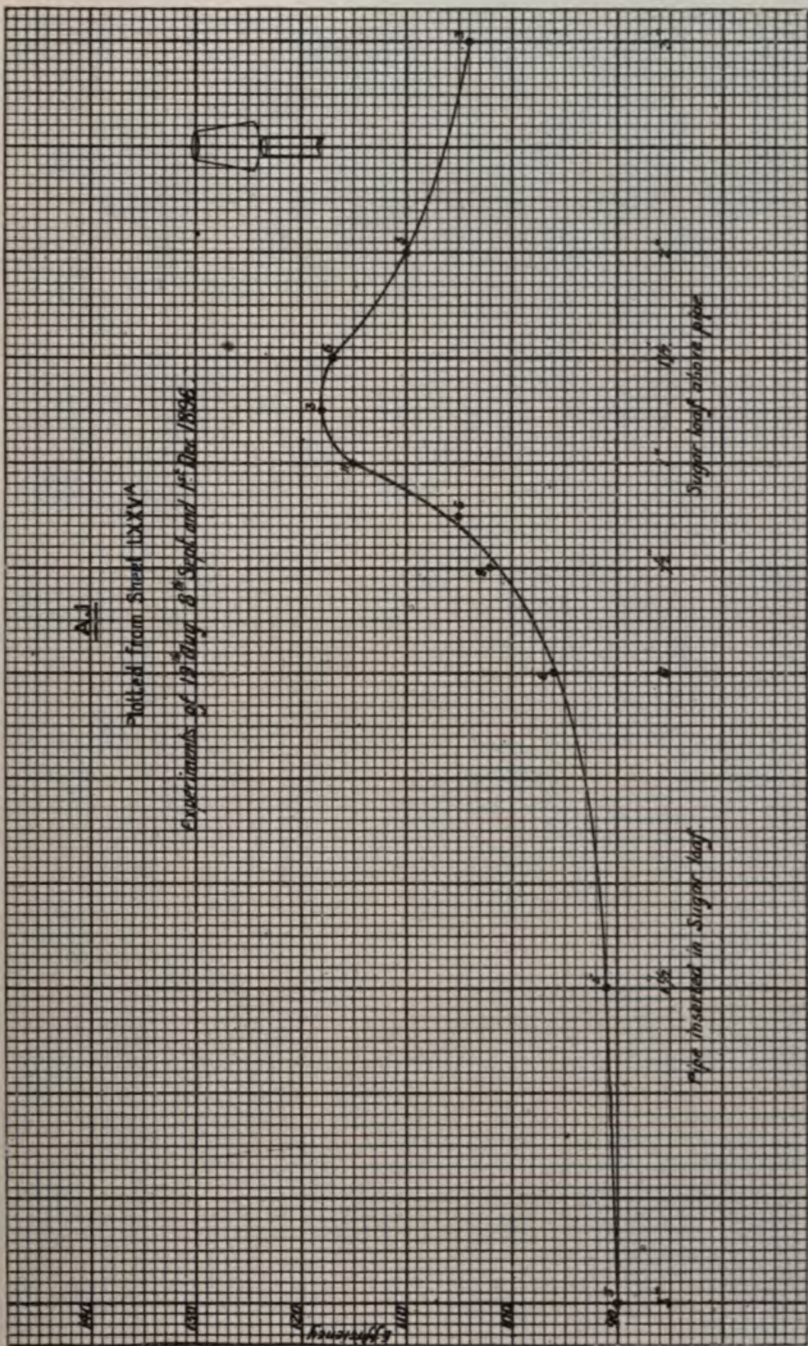

A.J.
Plotted from Sheet LXXV
Sugar loaf above pipe
Pipe inserted in Sugar loaf
Efficiency
140
130
120
110
100
90

Diagram 69.

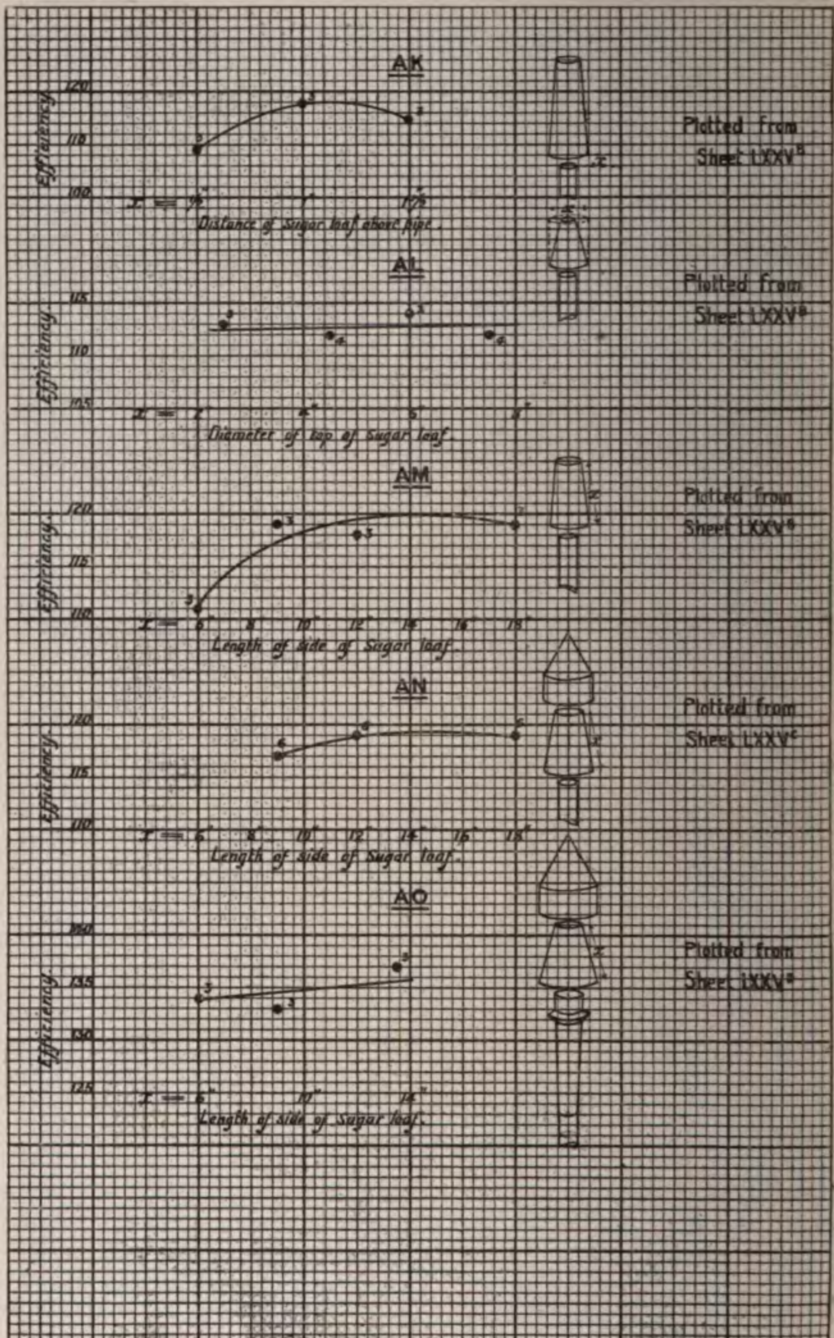

AK
Efficiency
120
110
100
Distance of Sugar loaf above pipe.
Plotted from Sheet LXXV
AL
Efficiency
115
110
105
Diameter of top of Sugar loaf.
Plotted from Sheet LXXV
AM
Efficiency
120
115
110
Length of side of Sugar loaf.
Plotted from Sheet LXXV
AN
Efficiency
120
115
110
Length of side of Sugar loaf.
Plotted from Sheet LXXV
AO
Efficiency
140
135
130
125
Length of side of Sugar loaf.
Plotted from Sheet LXXV

Diagram 70.

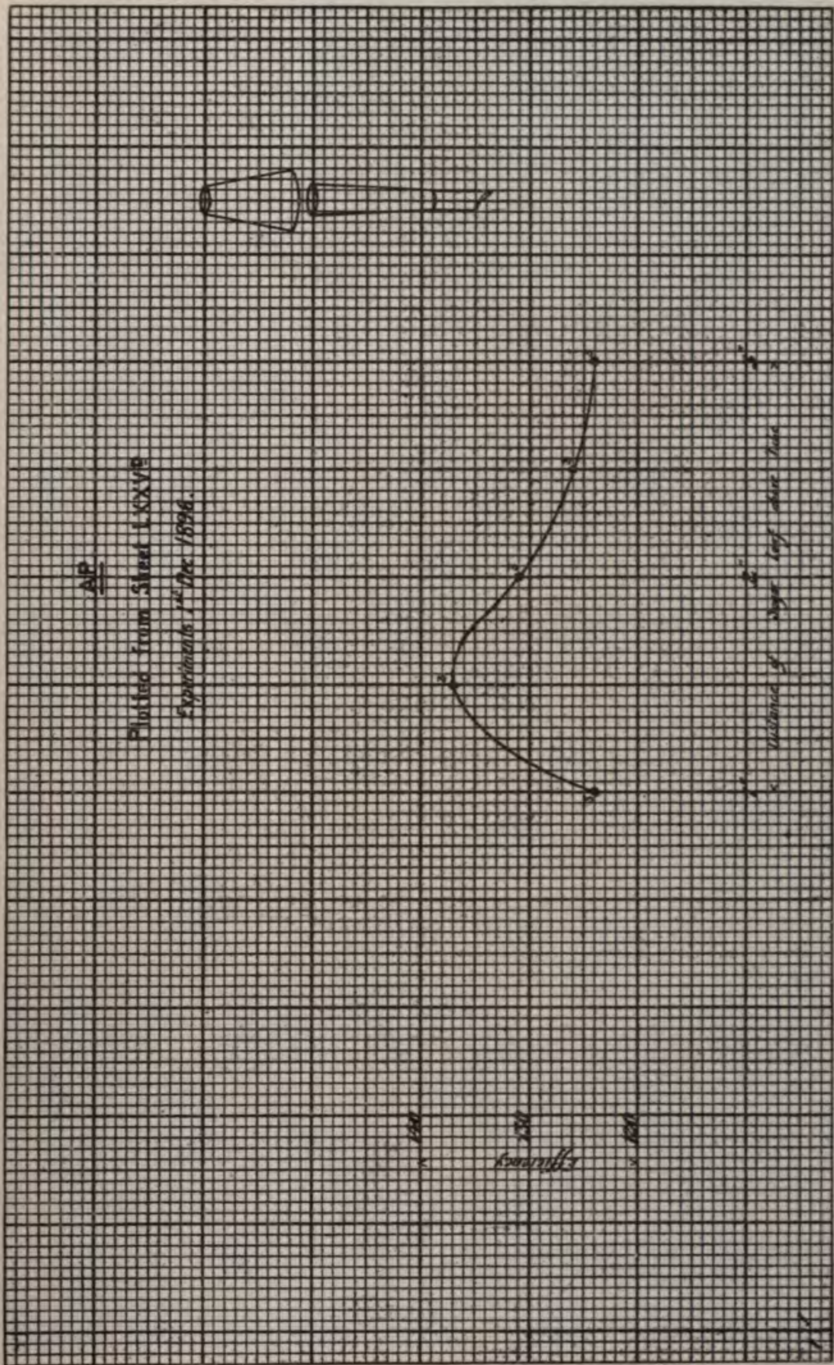
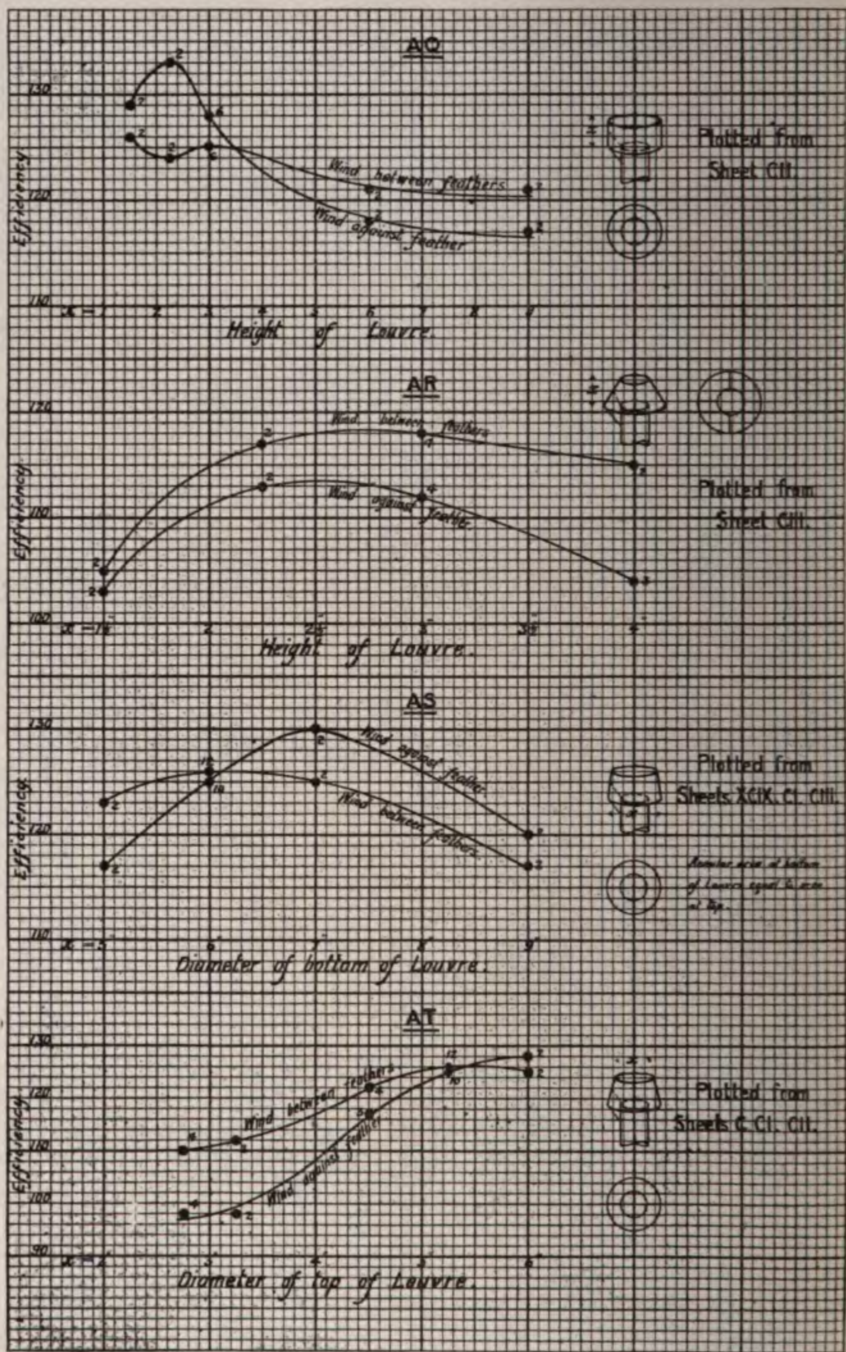
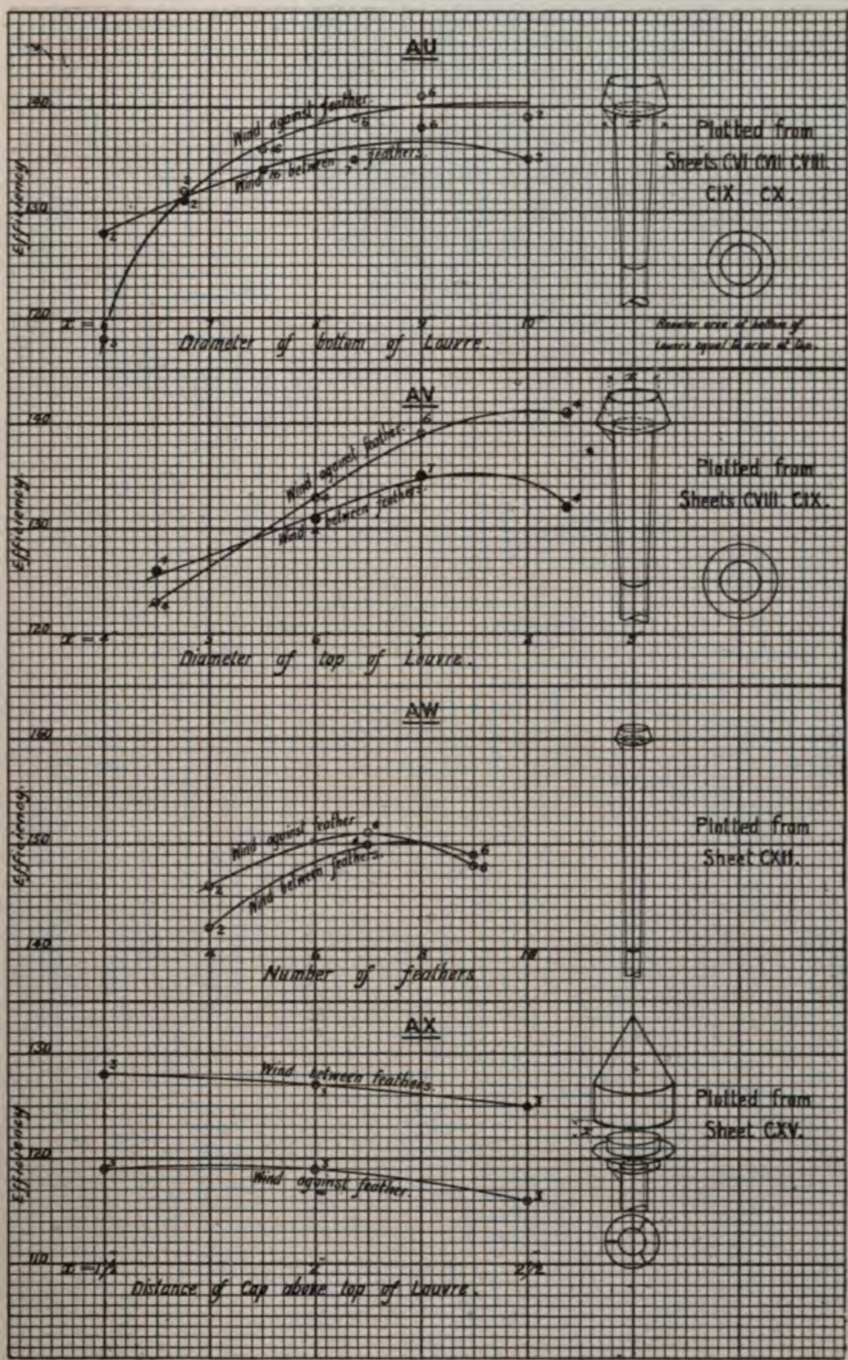


Diagram 71.



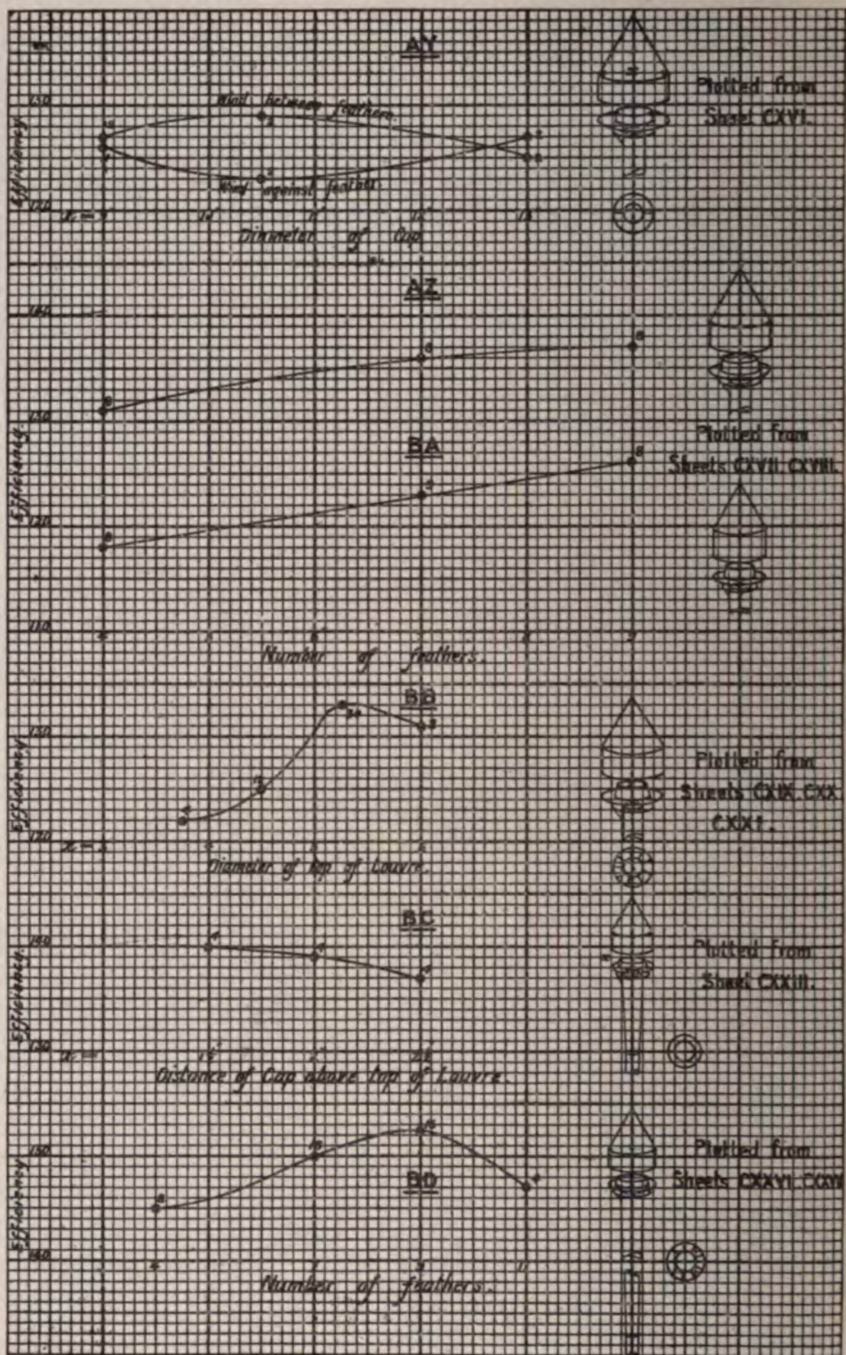
Terminals with 4 feathers.

Diagram 72.



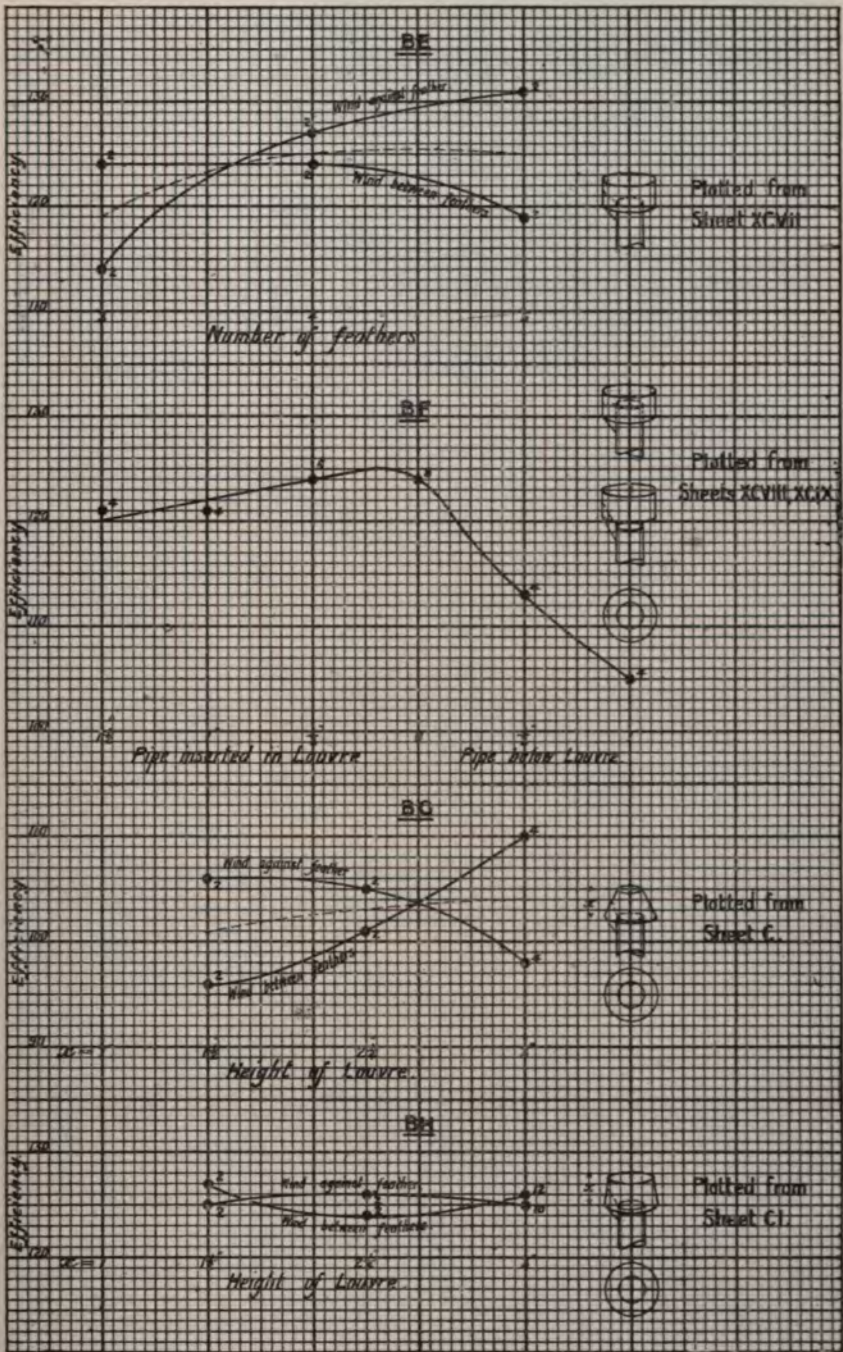
AU, AV, 4 feathers ; AX, 3 feathers.

Diagram 73.



AY, BC, 4 feathers ; BB, BD, 9 feathers.

Diagram 74.



BF, BG, BH, 4 feathers.

Diagram 75.

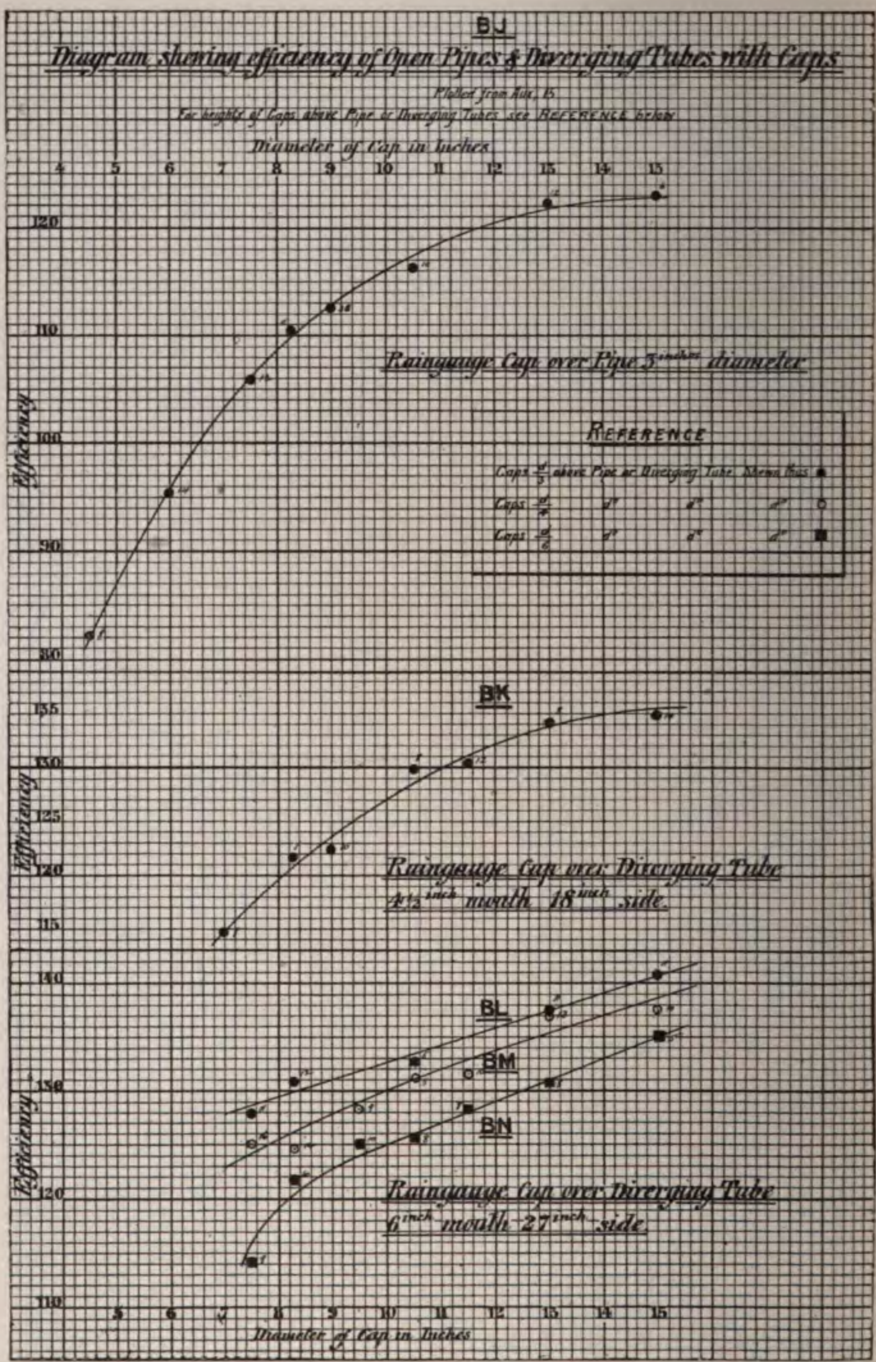
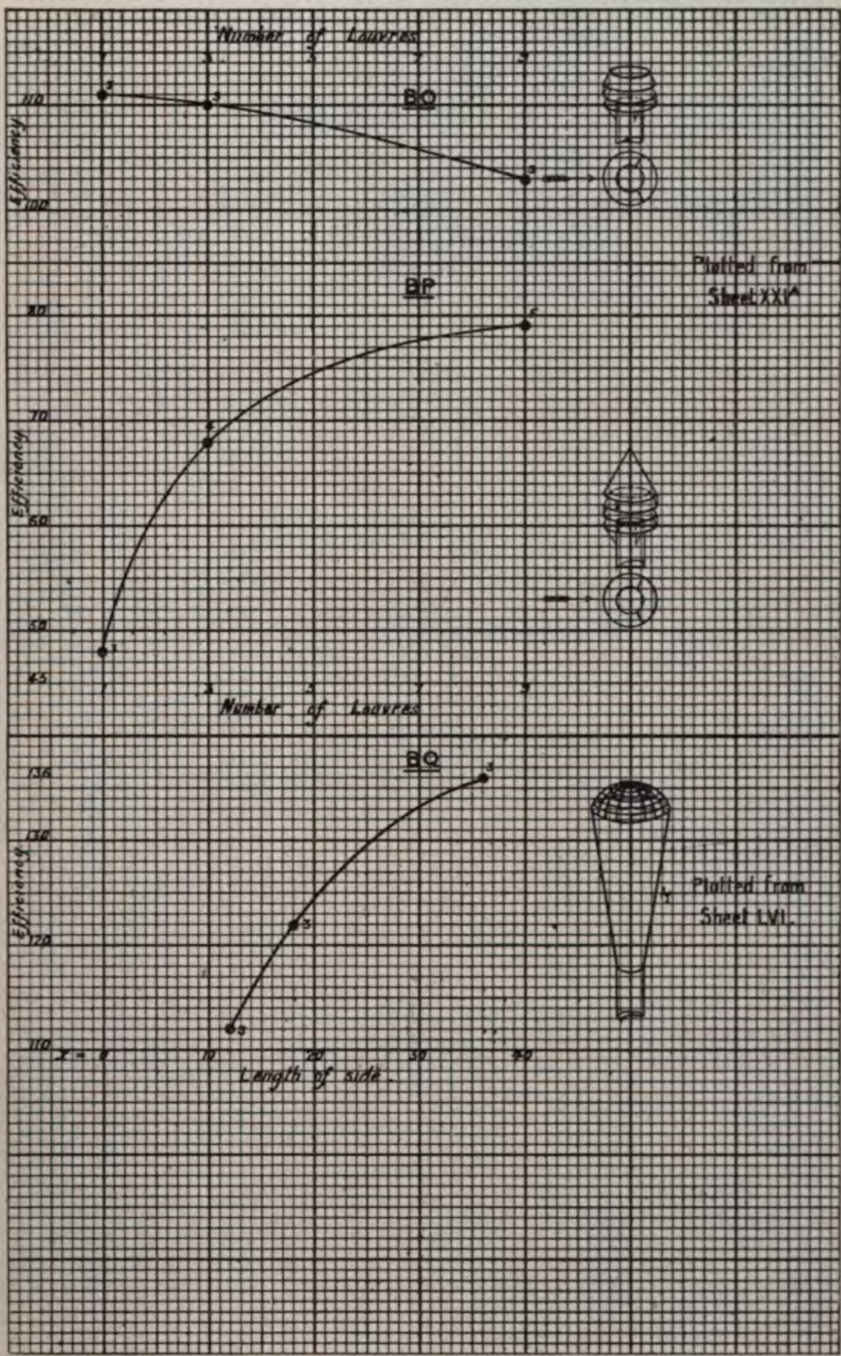
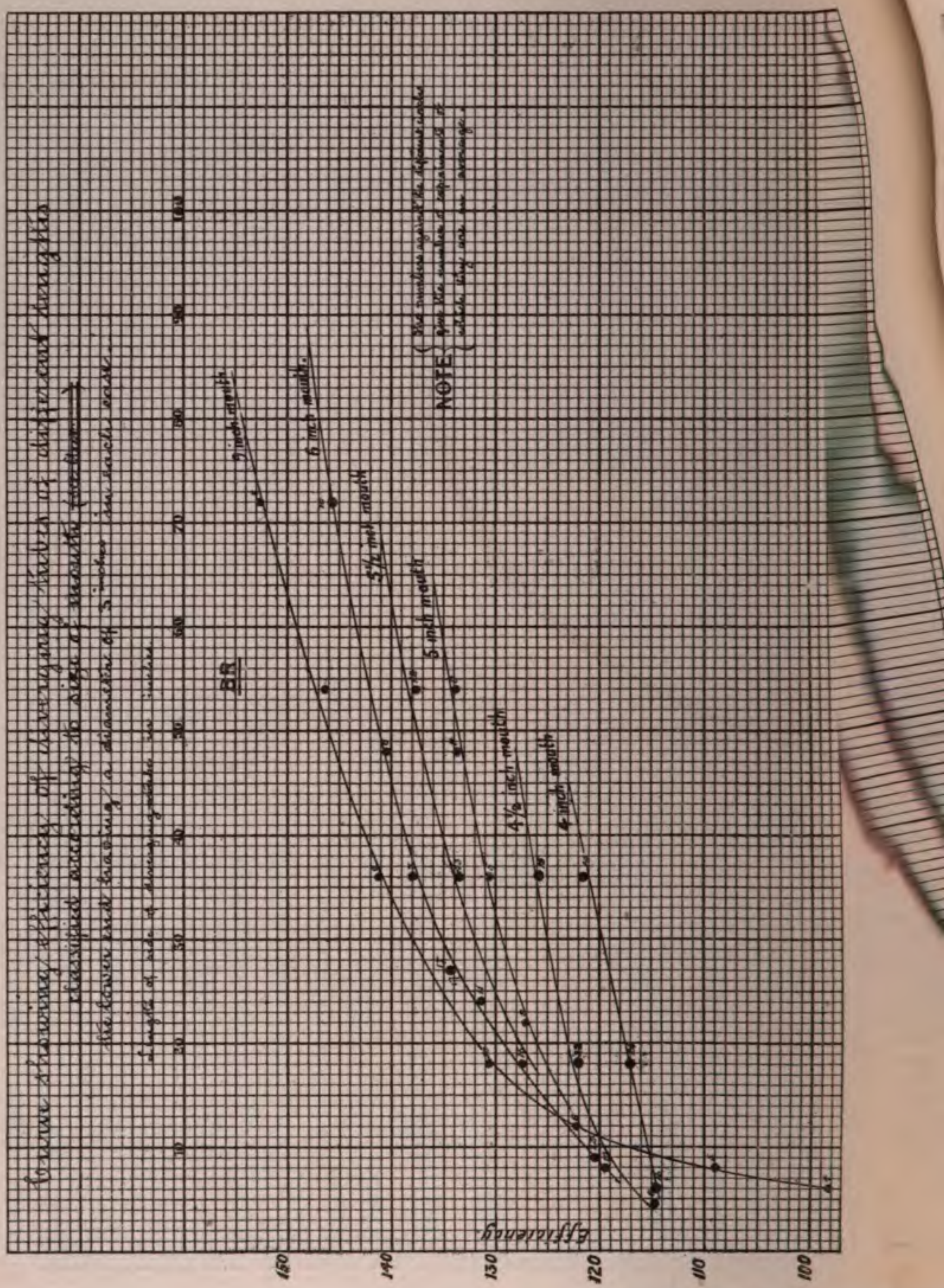

BJ
Diagram shewing efficiency of Open Pipes & Diverging Tubes with Caps
Plotted from Aux. 15
For heights of Caps above Pipe or Diverging Tubes see REFERENCE below
Diameter of Cap in Inches
4 5 6 7 8 9 10 11 12 13 14 15
120
110
100
90
80
Efficiency
Raingauge Cap over Pipe 3 inches diameter
REFERENCE
Caps d/3 above Pipe or Diverging Tube. Shewn thus
Caps d/4
Caps d/6
BK
135
130
125
120
115
Efficiency
Raingauge Cap over Diverging Tube
4½ inch mouth 18 inch side.
BL
BM
BN
140
130
120
110
Efficiency
Raingauge Cap over Diverging Tube
6 inch mouth 27 inch side
5 6 7 8 9 10 11 12 13 14 15
Diameter of Cap in Inches

Diagram 76.



BO, BP, 3 feathers.

Diagram 77.


Efficiency
150
140
130
120
110
100
10
20
30
40
50
60
70
80
90
100
BR
6 inch mouth
5 inch mouth
4 inch mouth
NOTE

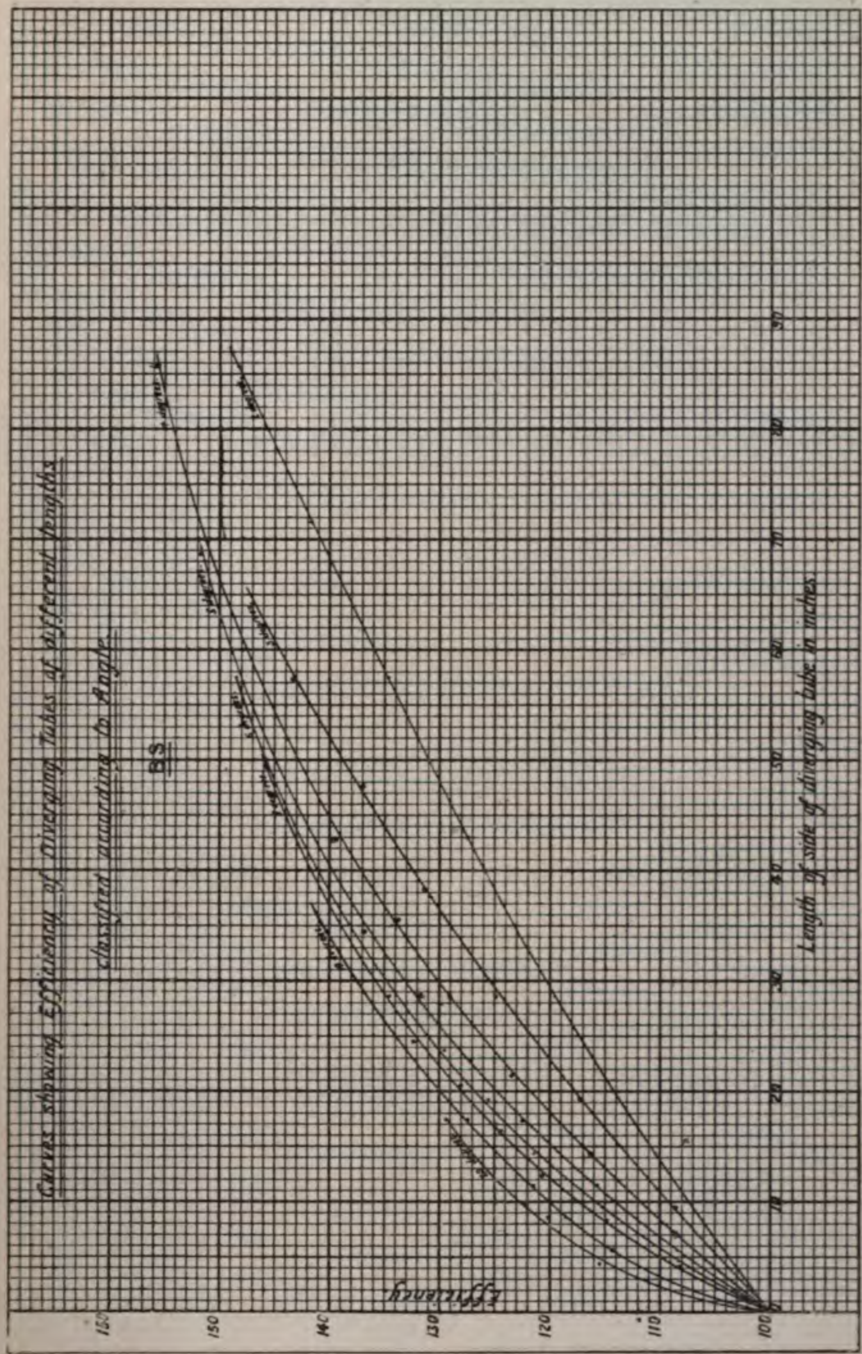

Curves showing Efficiency of Diverging Tubes of different lengths
classified according to Angle
BS
Length of side of diverging tube in inches
Efficiency
100
110
120
130
140
150
160
10
20
30
40
50
60
70
80
90

Diagram 79.

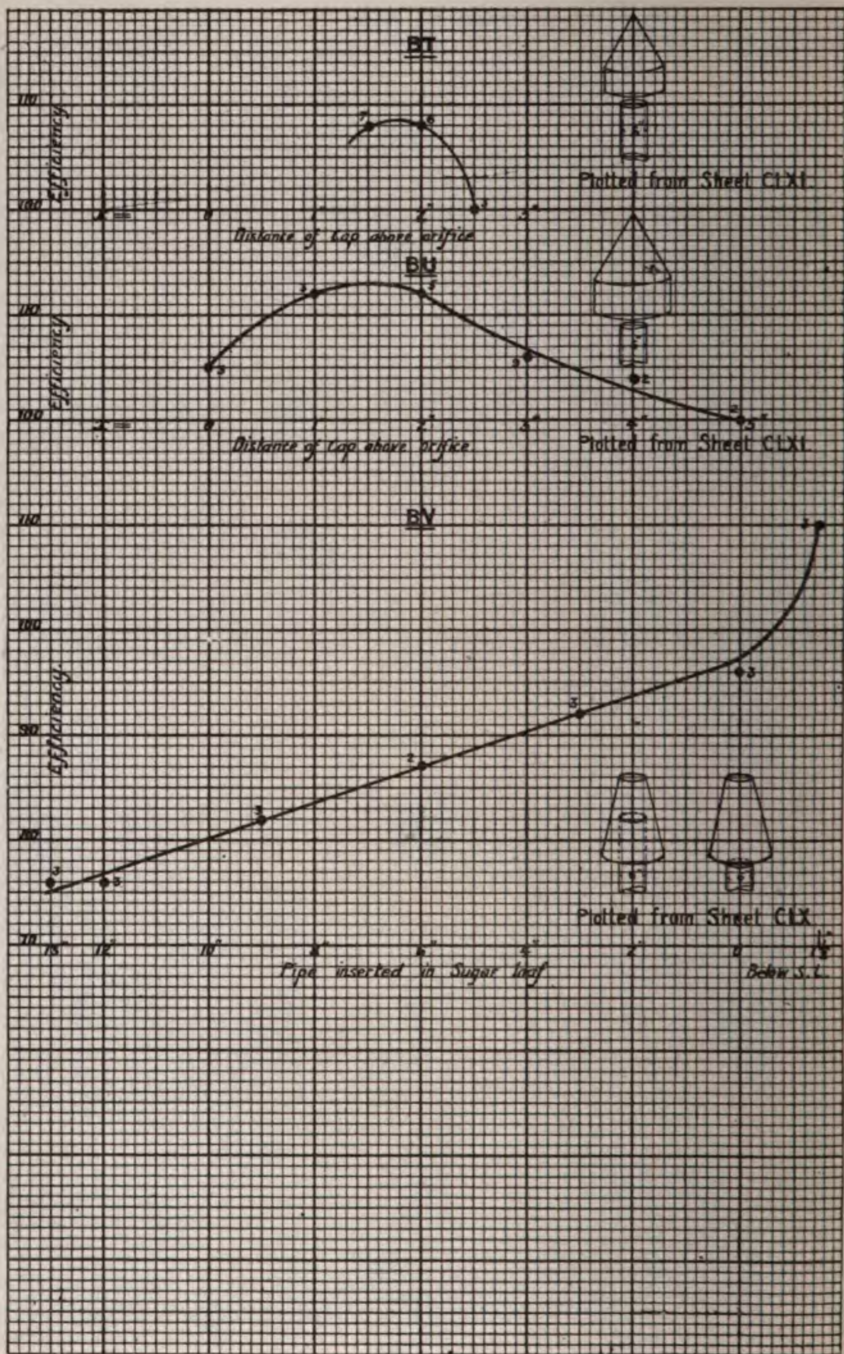

BT
Efficiency
Distance of Cap above orifice
Plotted from Sheet CLXI
BU
Efficiency
Distance of Cap above orifice
Plotted from Sheet CLXI
BV
Efficiency
Pipe inserted in Sugar loaf
Below S.L.
Plotted from Sheet CLX

Diagram 80.

Experiments on Sloping Roof, Angle 52°. Terminals 1 ft. above Ridge of Roof.

Curves showing the variation of efficiency with the direction of the wind.

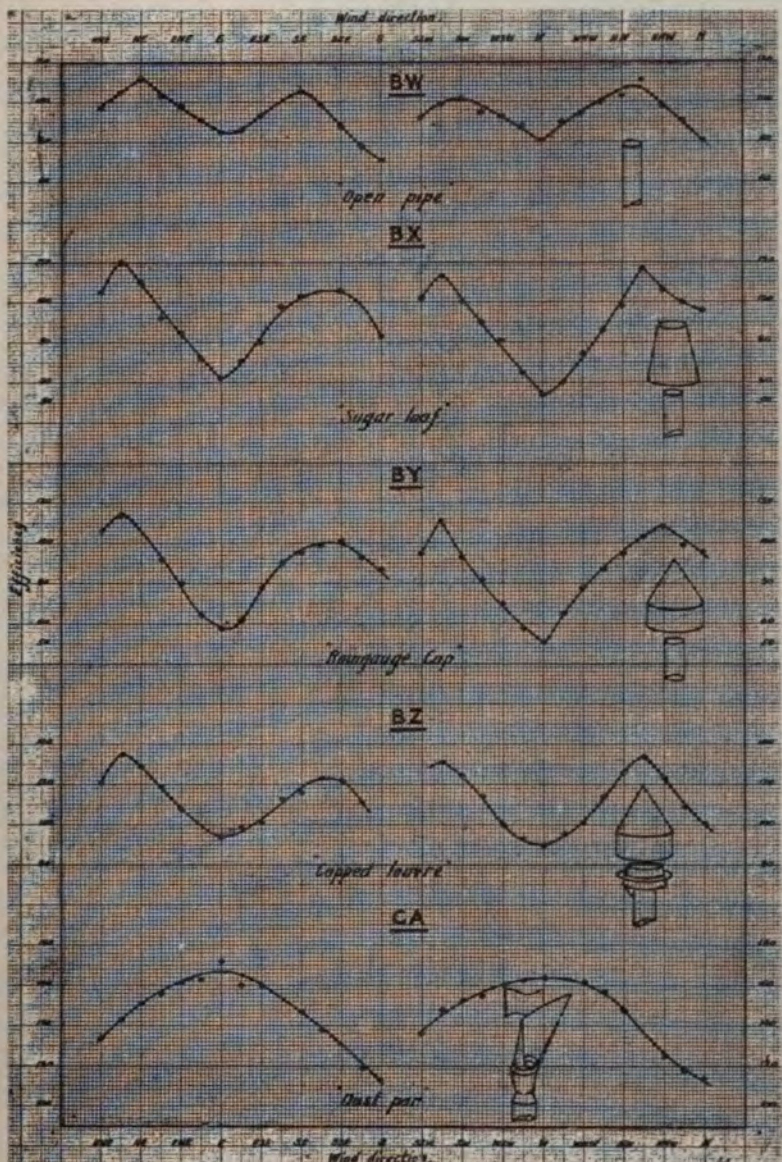


Diagram 81.

(See also Diagram 50, p. 339.)

Results of Experiments made in Winds Blowing at Angle from 78¾ to 90 degrees to Ridge.

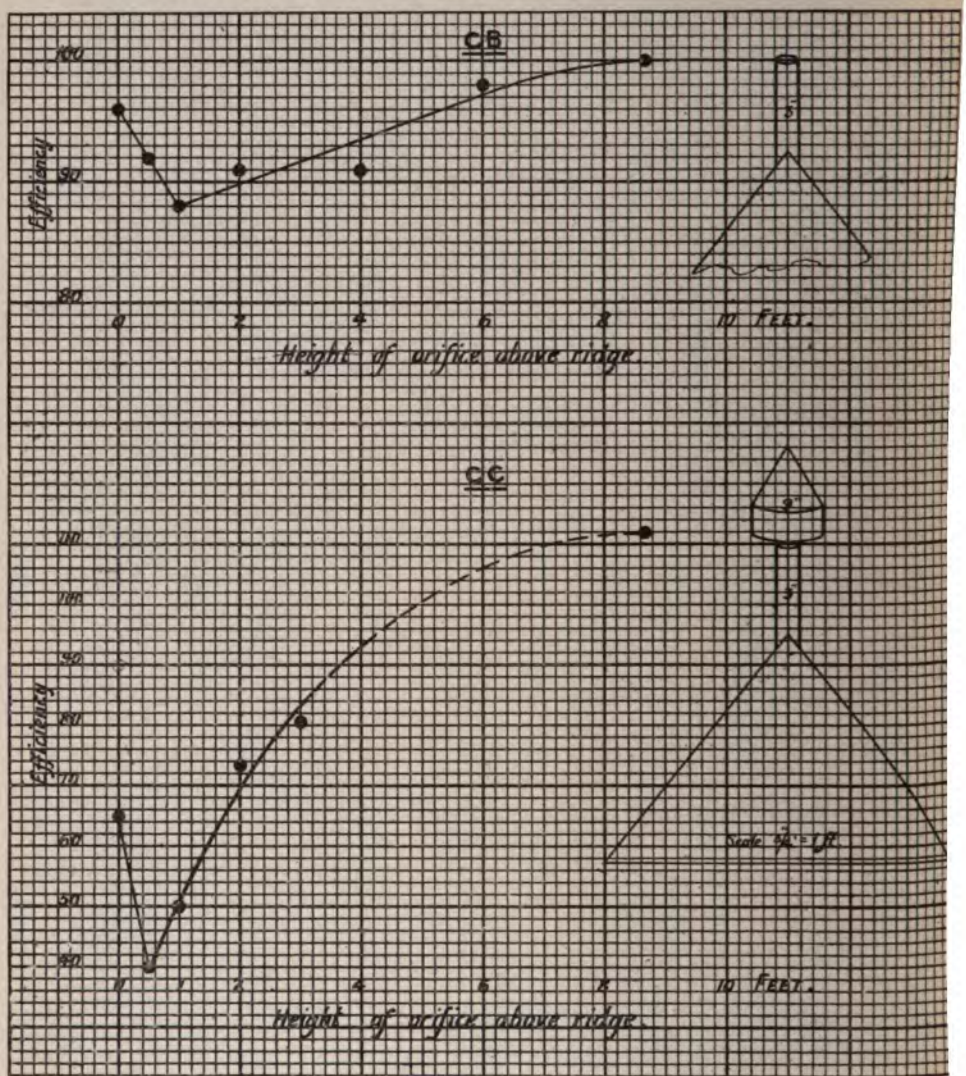
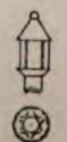
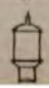


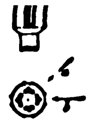
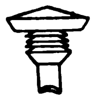
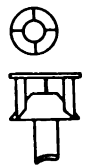
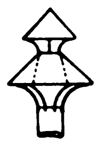
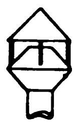
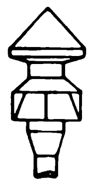
Diagram 82.

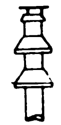
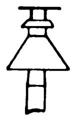
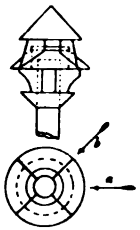
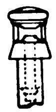
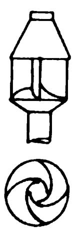
RESULTS FOR COWLS.

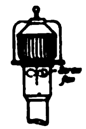
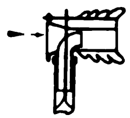
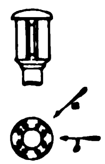
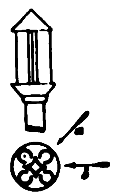
The results for Cowls have been treated in the same way as the results for Terminals, and are dealt with in Table XXIX. Many of the Cowls are well known by the names of the makers, but the satisfactory identification of all the Cowls in this manner would have involved a considerable addition to the labour of preparing the Report, as the history of each separate specimen was not recorded in a form which facilitated its identification; moreover, it was clearly impracticable to assign names to the 223 different forms of Terminals, and accordingly it seemed better to extend to the Cowls the practice adopted with Terminals and make a Scale drawing of each Cowl tested for identifying the particular form employed. A Scale drawing has accordingly been reproduced in the third column of the Table as in the case of Terminals. The general notes prefixed to the table of results for Terminals (see page 347) apply, generally speaking, to the following Table also:—

Table XXIX.—Reproduction of Results for Cowls.

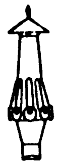
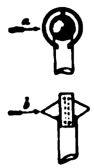
Sheet.	Date.	Sketch of Cowl.		Velocity of Cups, feet per minute. Max.	Velocity of Cups, feet per minute. Min.	Direction of Wind.	Efficiency. Max.	Efficiency. Min.	Efficiency. Average.	Number of Experiments	Reference Letters.	Angle from vertical at which downdraught is observed.	Remarks.
XVII[A.]	4 Aug., '84 15 Aug., '84 16 Aug., '84 18 Aug., '84 19 Aug., '84 20 Aug., '84 21 Aug., '84 26 Aug., '84 10 Sep., '84 11 Sep., '95	224 	....	704	136	From E. to N.N.W.	104	95	99	13	D B R*	A = down-blow. B = up-blow. See Remarks.	The difference between the maximum and minimum upcast efficiency may be accounted for by the setting of the cowl (shutter or opening) to wind. This compares with the 6-in. Cowl shown at Sketch No. 262. No downdraught observed. * See Sketch, No. 301, p. 444.
XII.	11 Aug., '84 15 Aug., '84 18 Aug., '84 19 Aug., '84 21 Aug., '84 26 Aug., '84 10 Sep., '84	225 	....	410	156	From E. to N.N.W.	104	92	97	9	......	See Remarks.	No downdraught observed. For explanation of the difference in upcast efficiency see remarks to Sketch No. 224.
XVII[A.]	20 Sep., '84 25 Sep., '84 21 Sep., '95	226 	...... a	488	288	From N.E. by E. to W.N.W.	103	93	97	4	......	See Remarks.	No downdraught observed. The ratio of the shutter to the opening of this Cowl differs from that of the 6-in. Cowl. For 6-in. Cowl of similar design, mounted on 3-in. pipe, see Sketch No. 263; and mounted on 6-in. pipe, see Sketch No. 268.
XVII[A.]	20 Sep., '84 23 Sep., '84 21 Sep., '95 18 Sep., '84 1 Nov., '84		...... b	408	113	From N.N.E. to W.N.W.	108	100	106	6			
XII.	26 Jan., '88 28 Jan., '88	227 	....	710	454	From N.W. to N.	85	68	77	4	......	....	For explanation of the difference in upcast efficiency, see remarks to Sketch No. 224.
XII.	19 Aug., '84 20 Aug., 84 27 Aug., 84	228 	...... a	470	145	From S.S.W. to N.	107	94	101	3			

XVII[B].	[illegible] Sep., '95 5 Sep., '95 14 May, '92 2 Sep., '95 5 Sep., '95	229		.... b	457	427	From S.W. by S. to W. by N.	98	92	96	6			[illegible] 264, and mounted on 6-in. pipe see Sketch No. 270.
XIII.	20 Aug., '86 24 Aug., '86 23 Sep., '86	230		....	351	194	From E.N.E. to N.	82	58	70	5	......	See Remarks.	No downdraught observed.
XIII.	11 Aug., '84 15 Aug., '84 18 Aug., '84 19 Aug., '84 20 Aug., '84 21 Aug., '84 26 Aug., '84 5 Sep., '84 9 Sep., '84	231		....	471	129	From S. to N.	84	67	73	9	......	B 50°	
XIV.	11 Aug., '84 15 Aug., '84 18 Aug., '84 19 Aug., '84 20 Aug., '84 21 Aug., '84 26 Aug., '84 18 Sep., '84	232		....	447	133	From N.N.E. to N.N.W.	108	97	100	8	......	B 30°	
XIV.	20 Aug., '84 21 Aug., '84 26 Aug., '84 27 Aug., 84 28 Aug., '84 29 Aug., '84 18 Sep., '84	233		... .	420	130	From N.N.E. to N.	86	75	79	7	......	30° *	* In this test the top of the pipe carrying the Cowl was inclined by a bend so placed that the wind blew at right angles to axis of Cowl.
XIV.	26 Aug., '84 27 Aug., '84 28 Aug., '84 29 Aug., '84 17 Sep., '84 18 Sep., '84	234		....	442	132	From N.N.E. to N.N.W.	98	92	95	7	......	B 30°	
XV.	22 Aug., '84 26 Aug., '84 27 Aug., '84 28 Aug., '84 18 Sep., '84	235		....	441	122	From N.N.E. to N.N.W.	75	67	71	6	......	See Remarks.	No downdraught observed.
XV.	27 Mar., '88	236		....	206	128	From W.S.W. to N.	80	70	75	4	.....	A 30°	

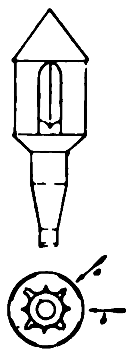
Sheet.	Date.	Sketch of Cowl.		...nute.		Direction of Wind.				Number Experim...	Refere... Letter	... at which downdraught is observed.	Remarks.
				Max.	Min		Max.	Min.	Average.			A = down-blow. B = up-blow.	
XV.	14 May, '92	237 	....	......	......	From W.S.W. to W.	61	61	61	2	......	See Remarks.	No downdraught observed.
XV.	14 May, '92	238 	....	......	......	From W.S.W. to W.	72	71	72	2	......	See Remarks.	No downdraught observed.
XV.	13 Nov., '84 14 Nov., '84 23 Dec., '84	239 	....	500	156	From N.E. to N.N.W.	115	76	92*	9	.....	See Remarks.	* Average of two experiments—with wind blowing from $a = 95$ with wind blowing from $b = 85$. No downdraught observed.
XVI.	9 Sep., '84 10 Sep., '84 17 Aug., '86 18 Aug., '86	240 	....	524	127	From E. to N.	63	44	49	6	......	B 10°	
XVI.	8 Nov., '84 18 Aug., '86	241 	....	163	120	From S.E. to N.N.W.	61	46	54	2	......	A 30° B 15°	
XVI.	17 Aug., '86	242 	....	430	211	N.N.W.	85	81	83	3			

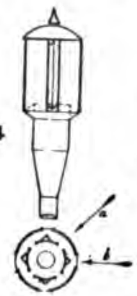
XVII.	28 Dec., '87 28 Jan., '88 28 Jan., '88	244		......	624	148	From N.E. to N.	97	21	68	9	......	....	EFFICIENCY. Higher openings to wind = 63. Lower openings to wind = 25. Meter stationary at intervals, but no backward movement indicating downdraught was observed. Plain side to wind......... = 90. Diagonally to wind ...... = 70.
XVII.	10 Feb., '94 24 Feb., '94	245		......	......	......	From W.S.W. to W.N.W.	65	59	63	3			
XVII. XVII$^{D.}$	11 & 15 Au. '84 18, 19, & 20 Aug., '84 10 Sep., '84 11 Sep., '95 12 May, '96 21 Sep., '95 21 May, '96	246		......	808	143	From E. by N. to N.	99	83	91	16	D B	....	For 6-in. Cowl of similar design, mounted on 3-in. pipe, see Sketch No. 285, and mounted on 6-in. pipe see Sketch No. 276.
XVII$^{D.}$	21 Sep., '95 21 May, '96	246a	Same Cowl, but with Screw-fan removed.		455	133	From E. by N. to N.N.W.	94	88	89	7			
XVII.	13, 15, 16, 18, 19, 20, & 28 Aug., '84	247		......	441	154	From S.W. to N.	77	57	66	8			
XVII$^{B.}$	15 Dec., '94	248		... *a*	702	578	W.N.W.	87	85	86	2			
XVII$^{B.}$	15 Dec., '94			... *b*	594	410	W.N.W.	92	91	92	2			
XVII$^{B.}$	17 Nov., '94 15 Dec., '94 19 Dec., '94	249		... *a*	601	327	From S.S.E. to W.N.W.	78	67	72	4	......	....	When set with opening to wind, this Cowl made a continual musical whistle like an Æolian harp.
XVII$^{B.}$	17 Nov., '94 15 Dec., '94 19 Dec., '94			... *b*	507	227	From S.S.E. to W.N.W.	81	75	78	4			

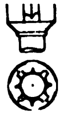
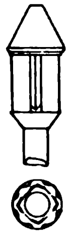
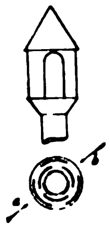
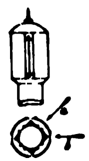
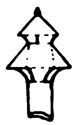
Sheet.	Date.	Sketch of Cowl.			Velocity of Cups, feet per minute.		Direction of Wind.	Efficiency.			Number of Experiments	Reference Letters.	Angle from vertical at which downdraught is observed.	Remarks.
					Max.	Min.		Max.	Min.	Average.				
													A = down-blow. B = up-blow.	
XVII^C.	5 Nov., '94 16 Nov., '94 15 Dec., '94	250		....	792	278	From S. to W.N.W.	88	81	84	6			
XVII^C.	19 Dec., '94 24 Dec., '94 28 Mar., '96 19 June, '96	251		....	722	113	From W.S.W. to N.N.W.	91	82	85	12	......	B 40°	
XVII^C.	19 June, '96	252		....	385	272	From W.S.W. to N.W.	63	59	61	5	DB		
XVII^C.	19 June, '96	253		....	470	402	From S.S.W. to S.W. by W.	65	63	64	3	......	....	For comparison with No. 252.
XVII^E.	19 Dec., '94 16 Apl., '95	254		....	650	407	From E. by N. to W.	96	91	93	5			
XVII^F.	10 Mar., '97 12 Mar., '97 8 Feb., '98	255		... . a	533	183	From S.W. to N.W.	83	80	82	6	S DB	....	No downdraught observed. For plan of this Cowl see Smoke Tests, p. 393.
XVII^F.	10 Mar., '97 12 Mar., '97 8 Feb., '98			... . b	596	316	From S.W. to W. by N.	87	80	84	6			
XVII^F.	8 Feb., '98	256		....	603	447	From W. to W. by N.	118	116	117	3	......	....	For comparison with No. 255. Drum surrounding pipe closed at top and bottom.
XVII^F.	8 Feb., '98	257		.... a	402	256	From W. by N. to W.N.W.	96	96	96	2	......	....	Same Cowl as shown at Sketch No. 255 but with cylinder of same diameter beneath.
XVII^F.	8 Feb., '98			.... b	345	322	W. by N.	98	98	98	2			

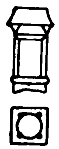
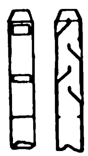
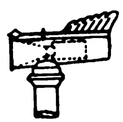
														
XVII^G.	10 Mar., '97 12 Mar., '97	259		...... a	417	274	From W. to N.W.	83	77	80	4	.....	B 40°	
XVII^G.	10 Mar., '97 12 Mar., '97			...... b	583	186	From W. to N.N.W.	92	79	84	4			
XVII^G.	10 Mar., '97 12 Mar., '97	260		....	603	435	From W.S.W. to W.N.W.	99	93	96	4	.....	A 40°	Same Cowl as the preceding but with cap removed.
XVII^G.	2 Feb., '98 5 Feb., '98	261		... .. a	941	269	From W.S.W. to N.N.W.	111	103	107	5			
XVII^G.	2 Feb., '98 5 Feb., '98			...... b	966	136	From W. to N.N.W.	63	54	58	5	D B S R*	....	* See diagram 56, p. 393.

6-inch COWLS ON 3-inch PIPE.

XVII^A.	11 Sep., '95	262		...... a	664	633	From S.W. to W.	101	100	101	2			
XVII^A.	11 Sep., '95			...... b	668	444	From S.W. to N.W. by W.	104	102	103	3			

Sheet.	Date.	Sketch of Cowl.		Velocity of Cups, feet per minute. Max.	Min.	Direction of Wind.	Efficiency. Max.	Min.	Average.	Number of Experiments.	Reference Letters.	Angle from vertical at which downdraught is observed.	Remarks.
												A = down-blow. B = up-blow.	
					6-inch COWLS ON 3-inch PIPE.								
XVII$^{A.}$	21 Sep., '95	263 	.... a	410	350	From N.E. by E. to E. by S.	110	108	109	2			
XVII$^{A.}$	21 Sep., '95		.... b	416	392	From E. by N. to S.E. by E.	112	112	112	2			
XVII$^{B.}$	2 Sep., '95 5 Sep., '95	264 	.... a	522	261	From S.W. by S. to W. by N.	114	110	112	4			
XVII$^{B.}$	2 Sep., '95 5 Sep., '95		.... b	530	226	From S.S.W. to W.	107	105	106	4			
XVII$^{D.}$	11 Sep., '95 21 Sep., '95 12 May, '96	265 	With Screw Fan.	614	136	From E.N.E. to W.	109	96	101	10			

	11 Apl., '87													
XVIII.	28 Feb., '87 8 Mar., '87 9 Mar., '87 26 Mar., '87	267		....	444	143	From N.E. to N.	103	95	99	6			
XVIII.	16 June, '88 4 Aug., '88	268		.... a	412	304	From N.E. to W.S.W.	102	98	100	3	......	....	For same Cowl mounted on 3-in. pipe see sketch No. 263. When the 3-in. Cowl was fixed with the shutter to wind the upcast efficiency was less than with the opening to wind, whereas, when the 6-in. Cowl mounted on a 6-in. pipe was fixed with shutter to wind the efficiency was greater (see Sketch No. 226).
XVIII.	16 June, '88 4 Aug., '88			.... b	438	414	From N.E. to S.W.	91	90	91	2			
XVIII.	28 Apl., '88	269		....	355	355	W.S.W.	...	...	56	1			
XVIII.	4 July, '92 6 May, '93	270		.... a	...	...	From E. to W.	102	100	101	4	......	See Remarks.	No downdraught observed. For same Cowl mounted on 3-in. pipe see Sketch No. 264.
XVIII.	4 July, '92 6 May, '93			.... b	...	...	From E.N.E. to W.	98	94	96	4			
XIX.	9 Mar., '97 26 Mar., '97 11 Apl., '87	271		....	640	266	From E. to N.W.	103	92	97	4	......	B 50°	

Sheet.	Date.	Sketch of Cowl.		per minute. Max.	per minute. Min.	Direction of Wind.	Max.	Min.	Average.	Number Experimen	Reference Letters.	vertical at which downdraught is observed. A = down-blow. B = up-blow.	Remarks.
XIX.	9 Mar., '87 26 Mar., '87 11 Apl., '87.	272 	....	601	233	From E. to W.	69	56	64	5	.....	See Remarks.	No downdraught observed.
XIX.	16 June, '88	273 	....	412	142	From N.E. to E.N.E.	75	74	75	2			
XIX.	4 July, '92 6 May, '93	274 	....	......	......	From E. to W.	53	52	53	4	......	B 60°	
XIX.	28 Apl., '88 22 June, '88	275 	....	405	184	From S.W. to N.W.	90	42	65	3	......	A 60°	Efficiency. Upper opening to wind=62. Plain side to wind =90. Lower opening to wind=42. Exhaust stopped at times.
XIX.	28 Feb., '87 8 Mar., '87 9 Mar., '87 26 Mar., '87 11 Apl., '87	276 	....	605	88	From N.E. to N.	96	76	89	6	......	....	For same Cowl mounted on 3-in pipe see Sketch No. 265.
XX.	15 Apl., '87 16 Apl., '87	277 	....	446	261	From E. to N.N.W.	56	46	52	6			
CLXXX.	1 Sep., '87		....	469	410	S.S.W.	......	......	......	......	......	B 60°	

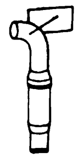
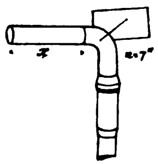
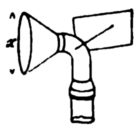
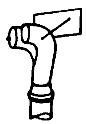
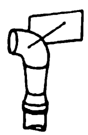
RESULTS FOR INJECTORS.

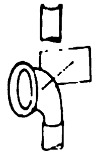
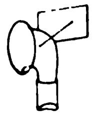
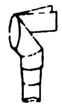
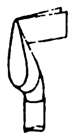
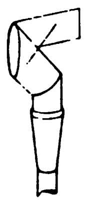
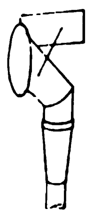
The next series of experiments to be referred to is that which is concerned with Injectors. For these experiments the injector cowl was mounted in place of the ordinary upcast cowl on the central pipe, and the reading of the air meter at the foot of the pipe compared with the corresponding upcast readings in the two outside pipes. It has already been pointed out (p. 340) that in an experiment of this kind the injector reading is not comparable with what would be obtained for the upcast cowl, because in the former case the injector is supplying air to the inside of the hut, and the external pipes are withdrawing it, whereas, in the latter, all three pipes are drawing air from the interior of the hut, which has to be supplied through the door or window or the casual openings. The high numbers obtained for the injectors must not therefore be regarded as being quite on the same footing as the numbers given for cowls. To make the experiments comparable with the cowl experiments, all three pipes should have had injectors mounted on them, and in that case the air supplied through the injectors would have had to find its way out of the hut.

It should be noticed that if the hut were perfectly air tight, except for the experimental pipes, the wind blowing across them could only produce an upcast in one if there were a downdraught in some other one, and three perfectly similar cowls upon three pipes should produce an actual balance, and there should be no flow of air up any one of the three pipes. Similarly with three equally efficient injectors placed upon the three pipes, no air could go down any one of them, unless there was some means for it to escape either up one of the other pipes or out of some of the other openings in the hut. It would in practice be impossible to get conditions so accurately the same even for two pipes, as to get an exact balance, and in consequence what one would expect with two similar cowls mounted upon a closed hut, is that there should be downdraught in one and upcast in the other, and the same would be the case with two injectors.

Injectors act by direct impulsion of the wind upon an orifice, and some contrivance must be made in every case to secure that the orifice faces the wind. If there is any want of sensitiveness in this respect, the injector is liable to fail in light winds, and may of course act as an upcast cowl if the orifice be away from the wind.

The results for injectors are contained in Table XXX.:—

Sheet.	Date.	Sketch of Injector.		Velocity of Cups, feet per minute. Max.	Min.	Direction of Wind.	Efficiency. Max.	Min.	Average.	Number of Experiments.	Reference Letters.		Remarks.
CXCII. CXCIV.	11 May, '96 15 May, '96 29 Jan., '98	279 	......	538	269	From N.N.E. to W.S.W.	169	149	159	9			
CXCII. CXCIV.	11 & 15 Ma. '96 26 May, '96 1, 4, & 7 July. '96 29 Jan., '98	280 	......	757	151	From N.N.E. to N.W. by N.	171	139	157	21			
CXCII.	11 & 15 Ma. '96		x= 19"	629	332	From N.N.E. to E. by S.	170	154	163	5			
CXCIII. CXCIV.	15 May, '96 26 May, '96	281 	x= 6"	832	178	From N.N.E. to N.W.	173	147	159	15	......	....	Compare with Sketch No. 280, with x=7".
CXCIII.	1 & 4 July, '96 29 Jan., '98 1 & 4 July, '96		x= 10"	789	168	From W.S.W. to W.N.W.	172	138*	156	7	......	....	* Probably due to Injector not answering properly to the wind, the velocity of the wind being exceedingly low during this test; this assumption is supported by the maximum injection, 172, being obtained in the highest wind.
CXCIV.	29 Jan., '98 2 Feb., '98	282 	......	734	292	From S.W. to W.	175	157	168	6	.....	....	This Injector was designed to compare with the Injector shown at Sketch No. 279, and when tested on the same day gave an average efficiency of 162, against 152 recorded by the Injector with single inlet.
CXCIV.	29 Jan., '98 2 Feb., '98	283 	......	991	327	From S.W. by S. to W. by N.	180	158	170	6			
CXCIV.	1 July, '96 4 July, '96	284 	......	908	126	From S.E. to N.W.	182	150	167	16	R	....	For Upcast form see Sketch No. 212 on Tabular Reproduction of Terminals.

CXCVI.	28 Mar., '96 8 Apl., '96 11 Apl., '96 25 Apl., '96 27 Apl., '96 11 Apl., '96	286		....	528	385	From W. to N.W. by W.	150	145	148	6			
CXCVI.	25 Apl., '96 27 Apl., '96 11 May, '96	287		....	543	354	From E. to W. by N.	172	133	148	8			
CXCV.	21 Feb., '95 10 Apl., '95	288		....	422	282	From N.E. to S.W. by W.	158	131	141	4			
CXCV.	27 Dec., '94 8 Apl., '96	289		....	513	289	From W. to N.	170	130	154	6			
CXCIV.	8 Apl., '96 11 Apl., '96 25 Apl., '96 27 Apl., '96 4 May, '96 15 May, '96 26 May, '96 1 July, '96 4 July, '96 7 July, '96 29 Jan., '98 2 Feb., '98	290		....	905	148	From N.N.E. to N.W.	183*	139	162	36	......	....	This was the highest individual result obtained; the two preceding experiments made on the same day when a strong West wind prevailed gave an efficiency of 180.
CXCVI.	25 Apl., '96 27 Apl., '96	291		....	533	357	From S.W. by S. to W. by N.	167	145	155	8	......	....	Although the general efficiency of this Injector is less than that of the preceding (see Sketch No. 290), when the two types were tried on the same day this Injector gave the better result of the two.

NOTE.—The efficiency of Injectors, as shown at Sketches Nos. 280, 281, 234, seems to improve as the winds get higher; but this remark does not apply to all other Injectors: at Sketch No. 290 the Injector is not apparently affected by the velocity, and Sketch No. 285 the efficiency is slightly decreased in high wind.

The difference of action in the two cases referred to above may be exemplified by some special experiments that were made to test the effect on injectors of opening and shutting of the door and window; see Diagram 83.

Arrangements for Testing the Effect of Wind on Injectors.

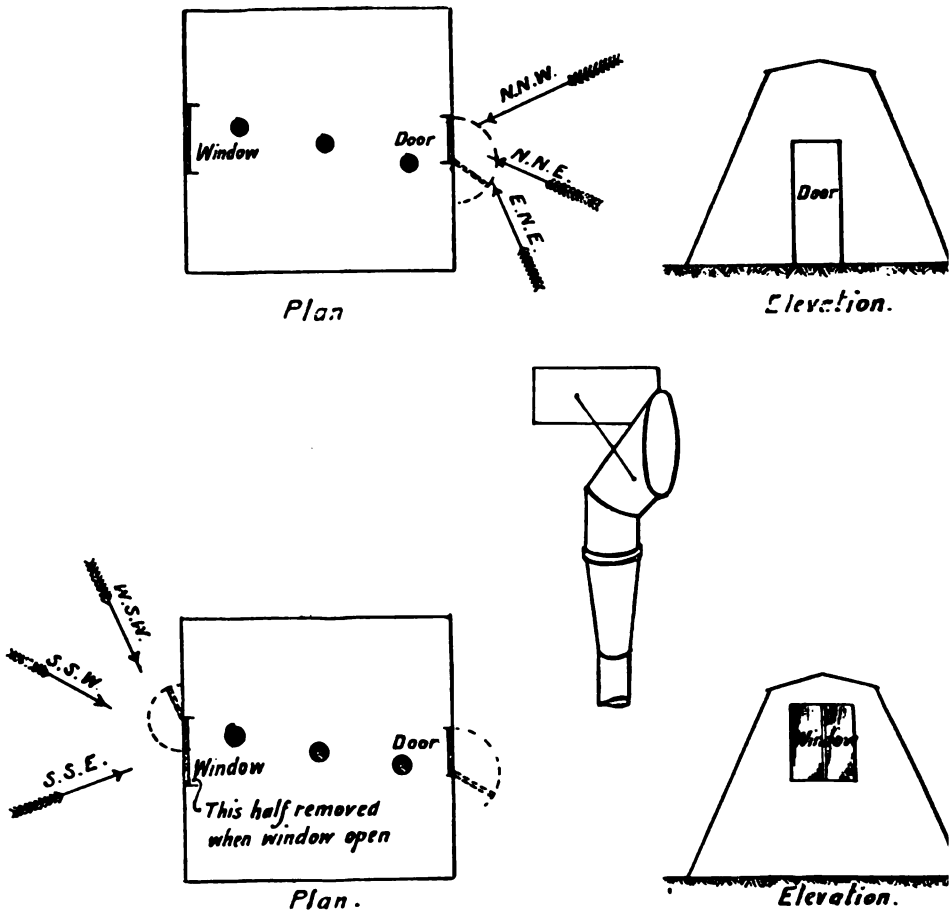


Diagram 83.

With the door open and the wind blowing in the quadrant between the face of shed and at right angles, on the side opposite to the hinges,

as much air practically went down the centre pipe as went up each of the outside ones, the efficiency being 1·12, but when the door was shut and the Injector became relatively a much more important air supply for the requirements of the two outside pipes, the ratio became 1·83. When the wind blew from the hinge side the effect of opening the door was much less marked, the ratios being 1·79 with door shut and 1·67 door open.

For winds on S side the window was used in the same way as the door for Northerly winds, and in these winds opening the window reduced the efficiency of the injector, as compared with the upcast in one of the pipes, from 1·67 to ·91, but with both window and door open the ratio of the injection to the upcast rose to 1·51.

EXPERIMENTS ON THE FAULTY SETTING OF TERMINALS AND COWLS.

About 52 experiments were made to test the effect of faulty setting of terminals upon pipes, or of the pipes carrying terminals. For this purpose the pipe with its terminal was inclined towards and away from the wind respectively, or the caps were tilted in their supporting pipes through definite angles which were indicated by specially constructed level gauges. The results show no marked effect in the former case, but in the latter it was observed the bad setting of a sugar loaf terminal, or rain gauge cap corresponding to a tilt of 1 in 28, might produce a decrease in the efficiency of the terminal to the extent of more than 5 per cent.

FURTHER EXPERIMENTS ON DOWN-DRAUGHT.

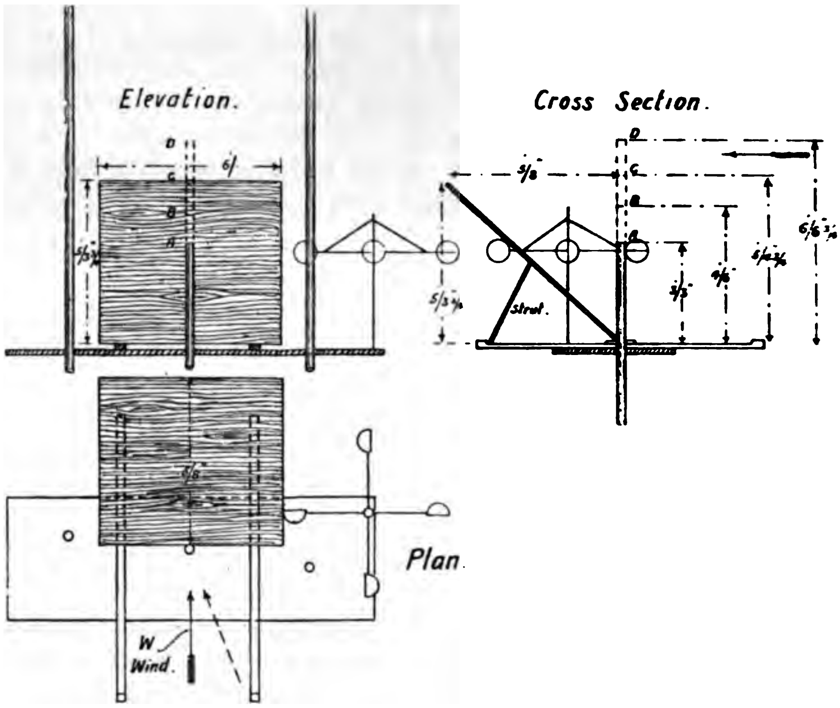
Besides the experiments on down-draught, of which results are included in the tabular statements for cowls and terminals, a number of others were made, and reference should be made to the following:—

(1.) Those included in Table XXVIII. p. 395, which gives the results of down-draught experiments upon terminals similar in shape but differing in dimensions from those referred to in the Diagrams 57–80. The letters in the first column of the table refer to the diagrams, and the details of the experiments will be sufficiently understood from the table wherein the letters A and B have the same signification as in the Tabular reproduction of results (see Table XXVII., p. 349).

(2.) A number of experiments known as "Experiments on Down-draught with Board," whereby it was sought to determine the effect upon a cowl or terminal by placing a board at various distances behind it across the direction of the wind. The arrangement of the board is represented in Diagram 85 (*a*) and (*b*), and the results will again be sufficiently understood from Table XXXI. (facing p. 440), wherein the letters have the following signification:—D denotes down-draught; S, stationary; U, upcast.

(3.) A few experiments were made with a board placed behind the middle open pipe, but inclined at an angle of 45° approximately to the

Proximity of Pipe to Sloping Roof.



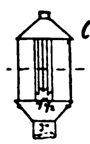
RESULTS.

3" Open pipe in position A 5/6" from slope. Downdraught Wind W. 15 miles per hour.

Do. Do. B. 5/- from slope. Downdraught W. wind some Upcast N.S.W. wind

Do. Do. C 6/8" from slope. Downdraught Wind W by S. 15 miles per hour.

Do. Do. D 5/8" from slope and 1/3" above top edge of slope. Meter stationary and momentary downdraught. Wind SW. and W.



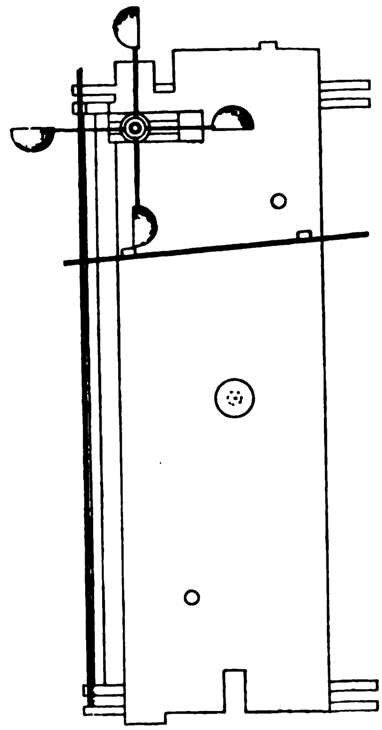
Centre of cowl same height as top of slope and 5/8" from slope. Downdraught Wind W. 12 to 15 miles per hour.

Diagram 84.

horizon, and so adjusted as to represent the effect of a sloping roof upon a pipe rising from the eaves.

The different experiments consisted in observing the occurrence of down-draught for pipes of different heights, and consequently having their orifice at different horizontal distances from the board. One experiment was also made with a Cowl. The results of the experiment are given in Diagram 84., p. 438, which sufficiently explains the arrangements.

PLAN.



FRONT ELEVATION.

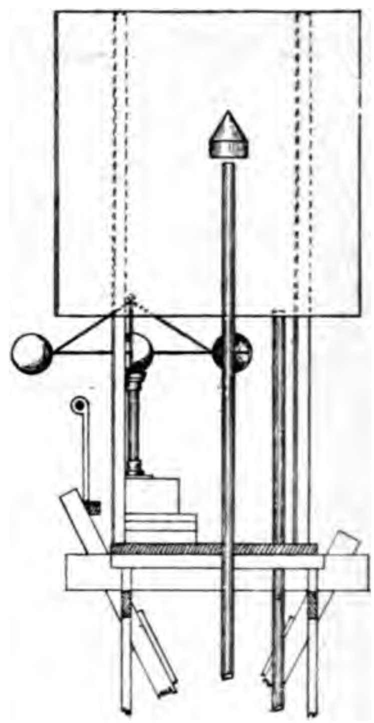


Diagram 85 (a).

...stances behind the centre of a Cowl or Terminal.

...ar reproduction, pp. 349, 389, 434.

	6 feet 6 inches from Board.			7 feet from Board.		
Result.	Date of Experiment.	Wind—Miles per hour.	Result.	Date of Experiment.	Wind—Miles per hour.	Result.
D & S						
D & S	3 May, '98	10 to 20	D & U	3 May, '98	10 to 12	S & U
....	3 May, '98	....	D & S			
D						
U						
D & U						
U						
U						
D						
D & S	3 May, '98	....	D, S, & U	3 May, '98	....	D, S, & U
U						
....	26 June, '96	8	U			
U						
....	26 June, '96	8 to 10	U			
....	26 June, '96	8 to 10	U			
D	3 May, '98	10 to 15	D & U	3 May, '98	10 to 15	S & U

...ilar to No. 94, but pipe inserted [illegible]-in. 8.—Similar to No. 104, but pipe inserted [illegible]-in.
...one 13-in. diameter.

The question of the effect of a ridge roof was still further investigated.

A few experiments were made upon the effect of a small, high-pitched roof with a roll ridge and an open pipe close up to the roll of the ridge, with its orifice flush with the top of the roll (see Diagram 86). The results are given on p. 443, and the different conditions of the several experiments are there specified. It will be seen that, under these circumstances, the roof improves the action of the pipe unless the wind is directed along the ridge, when the efficiency drops to about three-quarters.

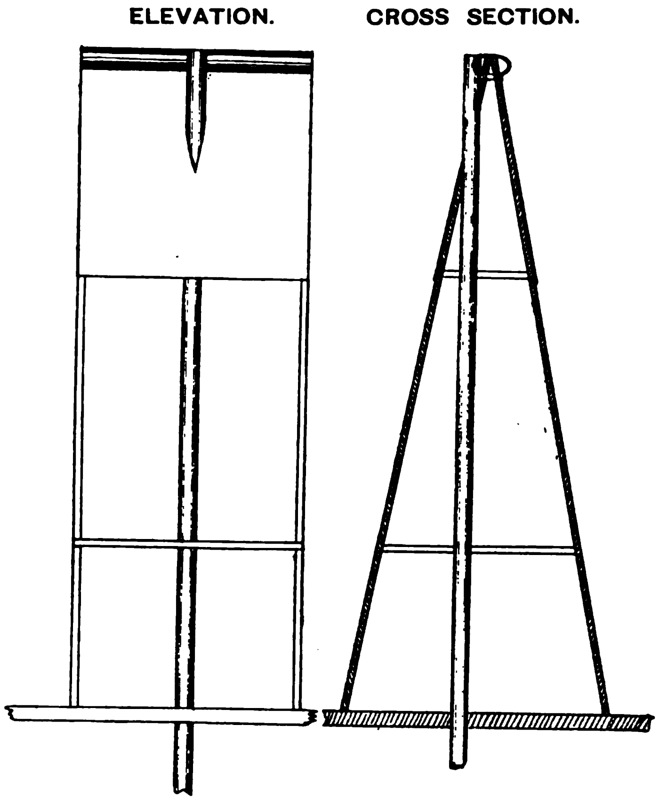


Diagram 86.

NOTE.—The ridge was 8 ft. 8 in. above, and the two outside open pipes 11 ft. 2 in. above platform. The mean of the two outside open pipes taken as 1·00.

Sloping roof fixed so that the ridge was practically in, and parallel to, the line of the pipes (N. by E. to S. by W.).

RESULTS OF EXPERIMENTS WITH SLOPING ROOF, NO. 3.

Pipe in front of sloping roof. Wind direction.	Efficiency.	*Pipe at back of sloping roof.* Wind direction.	Efficiency.
N.W. to W.N.W.	1·10	N.W. by N. to N.W. by W.	1·10
N.W. to W.N.W.	1·09	N.W. by N. to N.W. by W.	1·13
N.N.W. to N.W.	1·16		
N.N.W. to W.N.W.	1·12		
N.W. to N.W. by N.	1·21		
N.W. to N.W. by N.	1·14		

Sloping roof fixed so that the wind direction (N.W.) is along ridge.

RESULT.

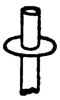
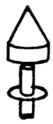
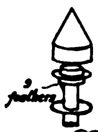
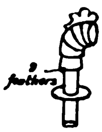
Wind direction.	Efficiency.
N.W.	·75
N.W. by N. to N.W. by W.	·74

RIDGE ROOF WITH PROJECTING PIPE.

The experimental work at the Hut included about 1,000 experiments of various kinds upon the effect of a ridge roof upon an open pipe, cowl, or terminal, mounted so that the opening was at various heights above the ridge. Practically all the experiments have been dealt with, but three selections are given in diagrammatic form as examples. First, Diagrams BW to CA, p. 421, Diagram 50, p. 339, exhibit the effect of changes in direction of the wind upon the upcast for an open pipe, and for a number of terminals which are indicated by small drawings in the Diagrams BX–CA. The curves show with conspicuous minima for the E. and W. points, and less conspicuous minima in the line of pipes, with maxima for angles approximately of 45° each way, except in the case of the dust-pan, which revolves with the wind and shows a maximum when the others show a minimum for the E. and W. points, and a minimum for the line of ridge. Secondly, Table XXXIII., p. 444 and 445, gives the results of experiments for a number of terminals and one cowl, for which there are not sufficient observations to draw curves; and thirdly, Diagram 84, p. 438, shows the effect of varying the height of the orifice above the ridge with the wind blowing nearly across the ridge—the most unfavourable position; the diagram sufficiently explains itself.

Table XXXIII.—Sloping-Roof Experiments

Orifice of Terminals 1 foot abov

	Sketch of Terminal.	N.N.E.	N.E. by N.	N.E.	N.E. by E.	E.N.E.	E. by N.	E.	E. by S.	E.S.E.	S.E. by E.	S.E.	S.E. by S.	S.S.E.
292		......	109	107	108	......	......	......	127 126	118	......	......	......	......
293		......	......	......	136	135 134	......	......	119	121	120	......	......	......
294		......	......	......	......	......	......	......	......	......	......	......	......	......
295		......	......	......	......	......	......	......	......	......	......	112	110	......
296		......	......	149 147 149	......	......	......	......	......	......	......	......	......	......
297		......	......	......	139 132	126	126	......	......	......	......	......	......	......
298		......	......	......	......	......	......	85	85 87	......	......	......	......	......
299		......	......	......	......	122	......	106	......	......	......	......	......	......
300		......	......	......	......	......	......	......	......	......	......	......	......	......
301		120 117 120	126 126	122 117	115 115 111 116 109 108	102 110 113 111 107	......	94 99 98 87 85 87 101	101 100	105 101 102	......	......	......	......

e Hut, Old Deer Park, Richmond, Surrey.

f Slope, 52°.

S.W.	S.W. by W.	W.S.W.	W. by S.	W.	W. by N.	W.N.W.	N.W. by W.	N.W.	N.W. by N.	N.N.W.	N. by W.	N.	
134	136	137	135 131	134	......	123	135	127	114	109 81	58 61	......	See also Diagram 60 N.
126	......	......	123 124 124	......	119	......	119	121	106	......	......	......	See also Diagram 60 N.
......	......	......	......	89 89 89 93 91	96	100 96	108	110	......	......	......	......	See also Sketch No. 108.
119	96 122	102	103 100 103 98	94 94 93 93	101	101 100	......	115	119 119	......	......	......	See also Sketch No. 73 and Diagram 60 O.
......	......	......	128 125	124 124 125	126 123	......	......	......	133	122	......	......	See also Sketch No. 157.
......	......	......	128	123 125	120 120 121	......	......	......	......	......	102 112	......	See also Sketch No. 210.
......	......	......	89 89	......	......	......	......	......	104 103	113	91 90 94	......	See also Sketch No. 198.
119	......	102	102 101	......	......	......	125	124	126	119	105 104	......	See also Sketch No. 204.
......	......	......	132 129 125	......	......	......	......	125 123	124	......	106		
119 117 116 116	116 114 114	107 110	101 102 102 102 107 105	95 99 106 99	95 92 104 105 100 107	102 101 101 104 112	......	118 116 112	113 111 105	97 94	87 91 89	80 79	See also Sketch No. 224.

General Note to Sloping Roof Tests.

The following is an enumeration of terminals also tried on sloping roof, the experiments upon which were too few to warrant their inclusion in diagrammatic or tabular form :—4½ ins. by 18 ins., diverging tube (see Diagram No. 78 BR, p. 418); ditto with 9-in. flange, 6-ins. from orifice; sugar loaf with fillet (see remarks to Sketch No. 110); twirling rain-gauge cap over diverging tube (see Sketch No. 213); and lobster similar to Sketch No. 198, but with flange 6 ins. below orifice of pipe.

At the time of Mr. Rogers Field's death, the experimental work in connection with sloping roofs was still in progress; it has not been completed, and the presentation of the results of the investigation of necessity exhibits this want of completeness. The numbers obtained are left to speak for themselves, without any attempt at expressing in general terms the comparisons that might be drawn between Cowls and Terminals of different types.

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INCEPTION

OF THE

"BOYLE" SYSTEM OF VENTILATION

(NATURAL).

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